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THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TRANSPORT HISTORY SPACE

INSIDE

ANIMAL ARMOUR

MEET THE TOUGHEST CREATURES ON EARTH

10 MATERIALS OF THE FUTURE

Find out what tomorrow's world will be made of

THE AMAZING STORY OF OIL

Follow the epic journey of the fuel that powers our planet

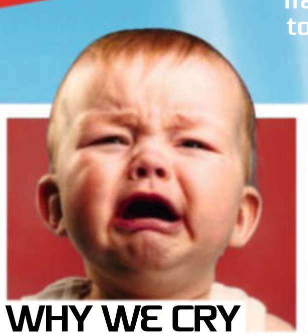
JETPACKS

DISCOVER THE FLIGHT REVOLUTION SET TO BLAST OFF

- HOW TO FLY A JETPACK •
- PERSONAL AVIATION TECH •
- JETPACKS IN EARTH'S ORBIT •
- WATER-POWERED PROPULSION •

AZTEC WARRIORS

The combat secrets of this ancient civilisation revealed



WHY WE CRY

How have tears helped the human race survive?

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ISSUE 058

DIAMOND RAIN IN SPACE

Learn about the weirdest weather in the universe

FOOTBALL SCIENCE

The physics that helps us bend it like Beckham

ISSUE 58

WELCOME

The magazine that fee

Page 24
Find out what ingenious ways nature has developed to defend itself against attackers

There are certain technologies that just shout 'THE FUTURE!' Hover cars are a classic example, as are colonies in outer space. And for many, jetpacks might fall into the same category, but there's one key difference: jetpacks exist today.

In our cover feature you'll find out why jet power is no longer the sole domain of rockets and aircraft as we focus on the amazing vehicles enabling us to fly solo. Find out what engineering powers the first commercial model – which could be up for grabs as early as 2015 – and also see how they measure up to other flying vehicles. Plus fearless aviation pioneer Yves 'Jetman' Rossy takes some time out from soaring alongside planes to talk to us about what the future holds for this burgeoning industry.

We also explain the epic journey of oil. While not without its controversy, for now our world couldn't run without it. When you consider what goes into its formation, extraction and processing, you'll feel a newfound respect the next time you fill up your tank. Enjoy the issue.

Adam

Adam Millward
Deputy Editor

Meet the team…

Marcus
Senior Designer
With a baby on the way, what better topic to explore than why we cry? At least now I know the reasons I'm getting next to no sleep!

Erlingur
Sub Editor
I love anything to do with artificial intelligence. Be sure to go to page 52 to get to know and accept our future machine overlords.

Jamie
Staff writer
Jetpacks have been the ultimate goal for easy travelling for so long, so the news that they could soon be commercially available is exciting.

Jackie
Research Editor
It may be controversial, but many aspects of modern life still depend on oil, including being able to read this magazine!

Helen
Senior Art Editor
I've loved learning about the incredible armour animals have developed to survive. You don't want to mess with these creatures!

Jack
Staff writer
It's been 100 years since WWI began and I was really interested to see exactly how the soldiers fought on the Western Front.

What's in store…

The huge amount of information in each issue of How It Works is organised into these key sections:

Science
Uncover the world's most amazing physics, chemistry and biology

Technology
Discover the inner workings of cool gadgets and engineering marvels

Transport
Everything from the fastest cars to the most advanced aircraft

Space
Learn about all things cosmic in the section that's truly out of this world

Environment
Explore the amazing natural wonders to be found on planet Earth

History
Step back in time and find out how things used to work in the past

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Follow the epic journey of the fuel that powers the world today, from how it formed millions of years ago to how it gets to the petrol pump

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Meet the experts...

Luis Villazon
Animal armour
Whether it's needle-like spines, tough exoskeletons or organic armour plating, Luis is here to reveal the amazing physiological features some of Earth's toughest animals use for self-defence.

Laura Mears
Jetpacks
This issue Laura gets up close and personal with the jet-powered machines ushering in a new era of personal flight. Find out how long it will be before flying takes over from driving.

Tim Hopkinson-Ball
Circus Maximus
Tim takes us on a guided tour of Ancient Rome's equivalent of Wembley Stadium, revealing how the venue was built how it changed with time.

Alexandra Cheung
The story of oil
Not without its controversy, oil still plays a massive role in fuelling the modern world. Alex takes us through the process, explaining where it comes from and where it goes.

Shanna Freeman
Space weather
Shanna shows us why we have things pretty easy on Earth when it comes to weather. If you thought *our* storms were bad, check out the forecast on other planets...

What happens to our body during zero gravity? Find out on pg 44

REGULARS

09

Meet the hybrid drone

Heli-truck cross ushers in new era of unmanned transport

As well as looking incredibly cool, this flying helicopter truck is a pioneer in modern transport. Similar to the drones that graced the cover of issue 54, it is unmanned and will primarily be used as a rapid-response unit in warfare. The Black Knight Transformer, as it has been named, boasts eight rotors for flight and can reach speeds of 112 kilometres (70 miles) per hour on the ground. Hybrid vehicles like this could revolutionise transport as we know it.

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Great white journey

Learn about a new science project aiming to shed some light on the mysterious migration of sharks across the oceans

A great white shark is currently undertaking an epic cross-Atlantic voyage. Marine biologists tagged the shark – nicknamed Lydia – as part of a scientific project designed to provide an insight into the species' movements. The reasons for the trek are yet to be understood but shark migration is well documented.

Currently travelling from west to east, the 4.4-metre (14-foot) beast began her marine adventure in Florida, USA, and is now on course for Cornwall in Britain.

Lydia is the first great white shark ever documented to cross the mid-Atlantic ridge and biologists predict she may continue toward the Mediterranean or even Africa.

Other long migrations

A few more creatures that make epic journeys

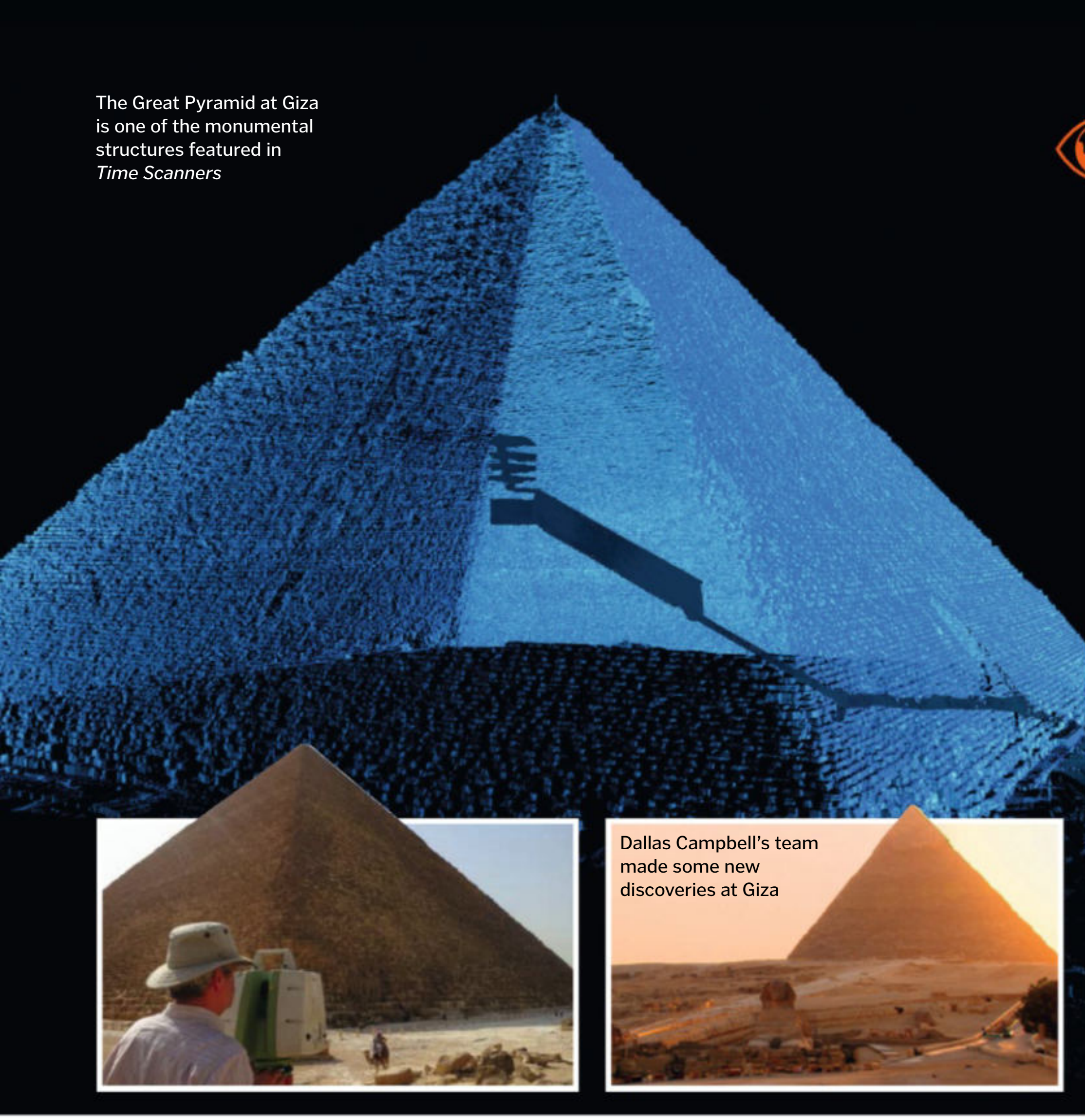
Wildebeest
They travel across the African Serengeti joined by zebras and gazelles for new grazing grounds.
Distance covered: ~2,900km (1,800mi)

Sea turtles
Migrating to warmer waters, they travel over great distances guided by the Earth's magnetic field.
Distance covered: ~16,100km (10,000mi)

Caribou
Traversing the Yukon and Alaska, the reindeer trek across swaths of icy tundra in search of food.
Distance covered: ~1,300km (800mi)

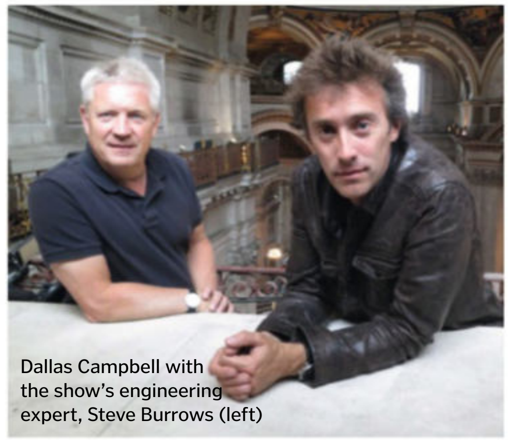
Bats
Some hibernate but others migrate to find warmer weather and more abundant food.
Distance covered: ~1,500km (950mi)

Salmon
Famous for their jumping, these fish swim for miles to spawn in the same river they were born in.
Distance covered: ~1,600km (1,000mi)



The Great Pyramid at Giza is one of the monumental structures featured in *Time Scanners*

Dallas Campbell's team made some new discoveries at Giza



Dallas Campbell with the show's engineering expert, Steve Burrows (left)

Filming in famous sites like Petra presented challenges with bureaucracy and tourists

Secrets of the past

Science TV presenter Dallas Campbell reveals how his new series lifts the lid on the impressive construction methods of ancient wonders

What are your first memories of science?
I suppose when I was very young, before secondary school, I was always fascinated by science. I was born at the time of [the] Apollo [lunar programme] so human space travel was very much in the human consciousness. My first memories of science probably came from *Look And Learn* magazine and far too much TV!

How did you get involved in science TV?
I guess I never lost my spark and interest for science. I remember [theatre director] Ken Campbell doing a show called *Reality On The Rocks*. There was this guy with no scientific experience trying to understand quantum mechanics. It was funny and witty and took you on a journey and I preferred this model to just professors and academics telling you things.

What's the main premise of *Time Scanners*?
The idea of the show is we want to look at some of the world's greatest structures and, using new technology, see how good yesterday's engineers really were. It's an opportunity to look at these structures you think you are familiar with but actually you're not. It was a journey of discovery, looking at new chapters from familiar stories. Steve Burrows, one of the world's greatest structural engineers – responsible for the Bird's Nest Stadium in Beijing and the Etihad Stadium in Manchester – was the man who looked at the data that came in, and told the story.

What technology did you use in the series?
Lidar was our main tool. Lidar is a machine that fires pulses of laser light at an object. The laser bounces back and you create a 'point cloud', which lets you create a 3D model of what you've scanned. Lidar lets you view these old buildings with a lot more accuracy than ever before.

We also used ground-penetrating radar (GPR), which fires radio waves into a narrow underground area so you can really see the structure. We used GPR a lot in Machu Picchu. The biggest challenge was access on a bureaucratic and physical level. They're full of tourists so you need to be nice to people and have a charm offensive. It takes a lot of time.

Did you make any new discoveries?
In the Great Pyramid we realised the King's chamber is in a different place than had been written about since its discovery in the 1880s. We thought everyone knew everything about the Pyramids, but there you go! The courtyard in Petra was something else. We know something's down there, but we didn't have the permits to dig so we didn't open up any fresh tombs or anything. We also did some neat calculations on how water got to Machu Picchu and King Herod's palace Herodium, which is not very well known.

***Time Scanners* is shown on Tuesdays at 9pm on National Geographic Channel. You can read an extended interview with Dallas Campbell on our website: www.howitworksdaily.com.**

10 COOL THINGS WE LEARNED THIS MONTH

Dark chocolate really is good for us

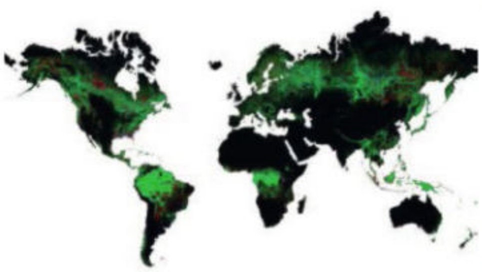
Chocolate might not be the first thing you'd think your doctor would prescribe, but a recent Dutch study has found a little dark chocolate can help ward off heart problems. While we've known for some time that cocoa has nutritional benefits, we haven't understood why. This latest research revealed that participants eating 70 grams (2.5 ounces) of dark chocolate per day over a month experienced improvements in vascular function. Arteries were more flexible and fewer white blood cells stuck to vessel walls – both of which reduce the risk of atherosclerosis (artery hardening) – the biggest cause of heart attacks.

Our pets see things we can't

Have you ever wondered why your cat has 'mad moments' where it seems to chase nothing, or your dog barks at thin air? The truth is, they may well be reacting to something out of our visual range. It's been known for some time that certain creatures like insects and fish see ultraviolet light, often using it as a guide to find their next meal, or to avoid becoming one. Now new research has revealed a far greater number of critters see some degree of UV, including cats and dogs, which might help explain some of their more unusual antics!

The Moon has a new crater

Astronomers in Spain have observed the biggest-ever impact on our Moon. Predicted to have weighed in at 400 kilograms (900 pounds), the asteroid was travelling at 61,000 kilometres (40,000 miles) per hour when it struck our satellite last September, resulting in collision energy equivalent to 15 tons of TNT.



Earth's forests are being watched

Using 500 million images captured by NASA's Landsat satellites, as well as reports from the ground, the Global Forest Watch is keeping a close eye on Earth's forests. All the raw data is fed into the Google Earth Engine, with algorithms created by the University of Maryland. The resulting maps reveal the shocking extent of deforestation in near real-time, with the images of threatened rainforest updated monthly. In the visualisation above red areas show the estimated 2.3 million square kilometres (888,035 square miles) of forest lost between 2000 and 2012.

Chickens eye up new state of matter

As if being the closest living relative of the T-rex didn't come with enough kudos, chicken's eyes could host a unique state of matter. Known as 'disordered hyperuniformity', the phenomenon has been studied in other materials, like plasma and liquid helium, for several years, but this is the first time it has been observed in a living organism. A cross between liquid and crystal states, disordered hyperuniform materials appear to have a haphazard structure on a micro level, but on a wider scale demonstrate rigid uniformity. Birds may have evolved this ordered chaos to get optimum vision out of small eyes.

Phones take on tsunamis

Although mobile phones are often lauded as being 'lifesaving' gadgets, it is generally more figurative than literal. Now a new mobile technology is transforming the ubiquitous device into an early-warning system, which sends text messages to those most in harm's way during a natural disaster. Developed by RegPoint, the innovative system is being launched in India this April, in conjunction with the Indian National Centre for Ocean Information Services (INCOIS). It will send an SMS alert to those signed up in at-risk areas immediately after a tsunami or typhoon has been detected and offer guidance of where to go and what to do.

Bubbles could fight urban pollution

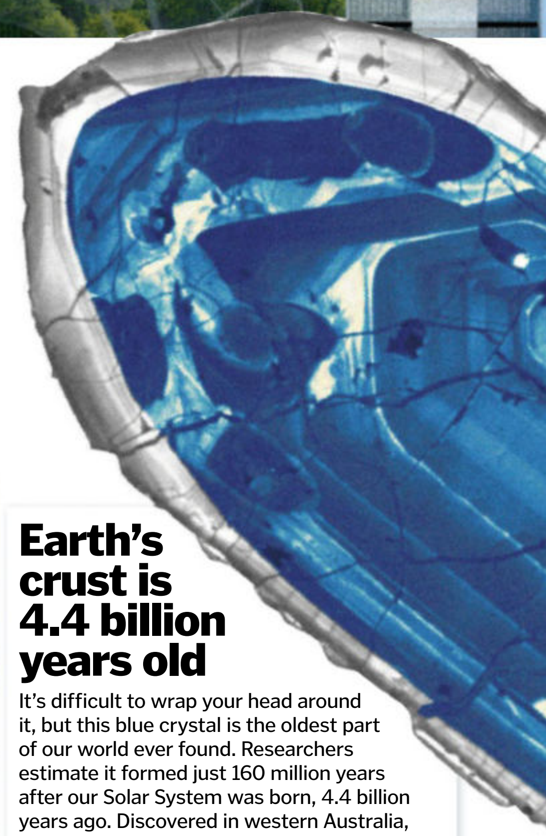
With pollution levels in cities around the globe ever rising, we've seen many proposals to generate cleaner air for city dwellers. Few are as extreme as the idea pitched by architectural firm Orproject though. They think the answer lies in urban parks enclosed in huge bubble-like domes made of light, transparent material based on natural structures like leaf veins. Because the gardens within the bubble are sealed, temperature and humidity can be monitored and controlled year-round and the air can be kept free of fumes and other contaminants outside. As well as public parks, the bubbles could also be adapted to sit over school playgrounds or apartment roof gardens.

Augmented reality is ready for the battlefield

Helmets have always been designed to save lives, but today's most advanced models do far more than just deflect incoming projectiles. Indeed, the Q-Warrior helmet-mounted display can help us see in the dark, provide detailed route maps through a war zone and even identify friend from foe – all on a mini screen directly in front of our eyes. The technology is likely to be issued to commanding officers on covert operations initially to help co-ordinate a team, but could one day be a part of every soldier's kit.

There is a new speed king in town

After several years of chasing the title, the Hennessey Venom GT has staked a new claim as the world's fastest production car. It reached 435.3 kilometres (270.5 miles) per hour on a NASA runway. Boasting a V8 engine with a ground-shaking output of 1,200 brake horsepower, it has just about bumped the archrival Bugatti Veyron off the top spot, which has held the record since 2010 at 431.1 kilometres (267.8 miles) per hour.



Earth's crust is 4.4 billion years old

It's difficult to wrap your head around it, but this blue crystal is the oldest part of our world ever found. Researchers estimate it formed just 160 million years after our Solar System was born, 4.4 billion years ago. Discovered in western Australia, the staggering age has now been confirmed using two dating techniques. Having previously measured the decay of uranium particles into lead, more recently the zircon crystal underwent atom-probe tomography that mapped out its atomic structure; both arrived at the same age. The team believe this discovery lends weight to the theory that Earth was hit by a planet-sized body in its formative years, leading to the Moon and a cooling process that resulted in our oceans.

JETPACKS

Almost 100 years after the jetpack was first conceived, modern technology is finally making personal flight a reality

5 TOP FACTS
JETPACK DANGERS

Flammable fuel
1 The Jetman's jet wing and the Martin Jetpack are both powered by explosive jet fuel typically used on larger aircraft, and so the pilot must wear a fire-retardant suit.

Noisy flight
2 The powerful fans keeping the Martin Jetpack and similar vehicles aloft in the air are so loud that the pilot is forced to wear ear defenders to protect their hearing.

Midair failure
3 If a jetpack engine cuts out midair, rapidly deployed ballistic parachutes can drastically slow your descent, but these only work if you're high enough from the ground.

Steam power
4 Hydrogen peroxide rocket packs use jets of steam and oxygen in order to get around. Less explosive than jet fuel but it puts the pilot at a great risk of burns.

Exhaust burns
5 Not only do pilots have to wear fireproof suits, but their feet also need to be protected from the high-temperature gases being emitted from the engine exhaust.

DID YOU KNOW? *A RB2000 rocket pack went missing shortly after its debut and its whereabouts is still unknown*

In the 1920s, Buck Rogers used a jetpack to fight crime in the comic *Amazing Stories*, offering a glimpse into a future where humans could fly.

A jet engine typically generates thrust by taking in air, mixing it with fuel, compressing it and igniting it. This hot, high-pressure gas is then passed through a turbine and out through a narrow nozzle, producing thrust. The gold standard for a jetpack would be to mount one or more of these powerful engines onto a backpack, enabling the wearer to fly freely in any direction.

However, early jet engines were too large to be worn by a person, so the only alternative was to use rockets. Rockets work on a similar principle to jet engines, but instead of taking in air, the rocket uses self-contained chemical reactions to generate power.

The first proper attempt at a jetpack – the rocket belt – was invented by Wendell Moore in 1953, and flew using hydrogen peroxide rockets. A tank of nitrogen gas forced hydrogen peroxide through a silver catalyst, causing it to rapidly break down into steam and oxygen. The gas shot out of the nozzles at 1,000 metres (3,280 feet) per second, producing over 125 kilograms (280 pounds) of thrust. This was powerful enough to lift the rocket belt and its wearer into the air for just over 20 seconds.

However, 70 per cent of the fuel in a rocket belt is required just to overcome the force of gravity, severely limiting flight time. Adding more fuel made the rocket belt too heavy to fly, so even with improvements in design and weight reductions using lighter modern materials, hydrogen peroxide rocket packs still cannot fly for more than a minute.

One solution to the problem of heavy fuel is to attach the jetpack to a flexible supply hose, tethered to a fuel source on the ground. While this seems impractical for a jetpack built for long-range transport, for recreational models, like the water-powered JetLev, this technique works well to extend airtime without weighing the pilot down (for more detail see the 'Flying with water jets' boxout on page 19).

The other alternative is to use a more efficient engine. Advances in jet engine technology have allowed the production of units small enough to fit on a backpack, paving the way for the development of real jetpacks today.

The idea was trialled by the rocket belt's inventor, Moore, in the late-Sixties using a custom-designed jet engine. Moore's jet belt was capable of keeping someone airborne for ▶

The Jetman and his jet wing

A pilot turned inventor, Yves Rossy became the first man to fly using a jet-propelled wing. The Swiss-made machine began as a winged suit to glide through the air but Rossy soon began experimenting with engines. At first, two model jet turbines were used, but this was upgraded to four as it could only just maintain level flight. A handheld throttle controls the jet wing and it can climb at a rate of 330 metres (1,080 feet) per minute. There have been over 15 prototypes over ten years of development. The current model is powered by four turbines and can reach speeds of 300 kilometres (186 miles) per hour. In 2008, Rossy crossed the English Channel and since he has flown with a Spitfire and across the Grand Canyon.

"An alternative to improve flight time is to abandon jet power and turn to different means of becoming airborne"

up to 20 minutes, at speeds of 97 kilometres (60 miles) per hour. However, the combination of a powerful jet, expensive, explosive fuel and a low-tech parachute system, made the jet belt impractical and pretty dangerous to fly.

One of the most impressive personal flying machines built using jet engines today is the jet wing, designed and piloted by Swiss inventor Yves Rossy (see the 'Jetman and his jet wing' boxout on page 13). The semi-rigid carbon-fibre wing is just over two metres (6.6 feet) across and is attached to four modified kerosene-fuelled jet engines. Jet engines are significantly more powerful than rockets so it takes just slight movements of the head, arms and shoulders to steer the wing. However, this body control makes it impossible to launch the jet wing from the ground. Instead, the wing is deployed from a helicopter and the engines are used in a kind of powered freefall, allowing Rossy to fly through the air at an average speed in excess of 160 kilometres (100 miles) per hour.

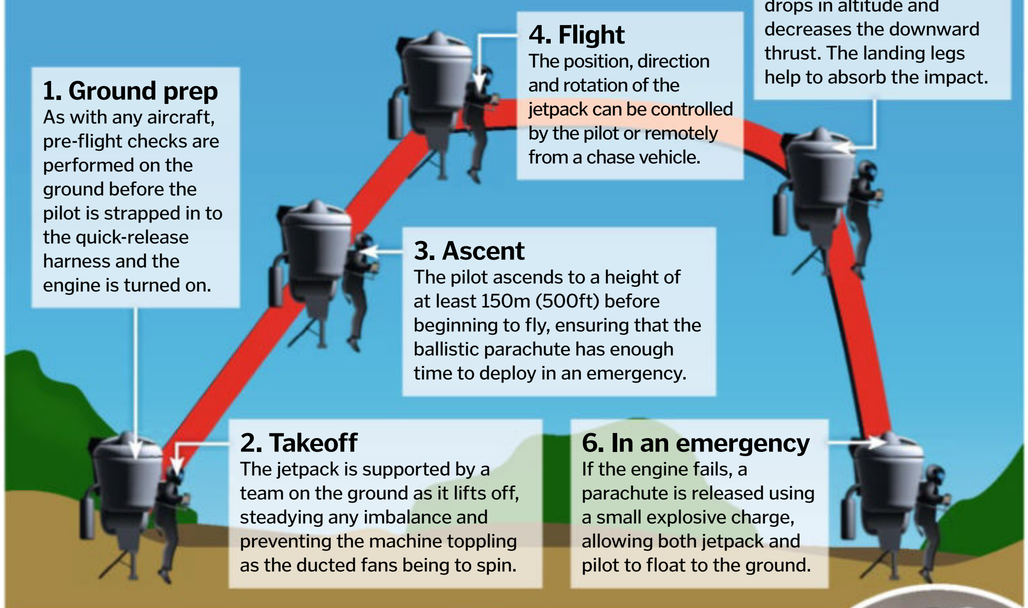
Another alternative to improve flight time is to abandon jet power altogether and turn to different means of becoming airborne.

Enter the Martin Jetpack. Instead of using jet engines this relies on twin-ducted fans to generate lift. Positioned on either side of the pilot, the two carbon Kevlar fans are driven by a bespoke V4 engine. The ducts are wider at the inlet than at the outlet, funnelling air through at high speed, and producing enough thrust not only to lift the jetpack and its pilot into the air, but also leaving an extra 50 kilograms (110 pounds) of thrust spare for rapid changes in altitude. The Martin Jetpack can climb at nearly 250 metres (800 feet) per minute.

The ducted fan design and petrol-powered engine enable this jetpack to reach top speeds of 74 kilometres (46 miles) per hour, with a

Flying a jetpack

A step-by-step guide from takeoff to landing



Two massive fans propel the Martin Jetpack through the air

The rise of jetpacks

The biggest milestones in personal aviation

Hiller VZ-1 Flying Platform
In 1955, Stanley Hiller develops a flying platform based on a 1.5m (5ft) ducted fan with two counter-rotating propellers. The pilot stands on top and uses their body weight to balance the machine.

Jump belt
In 1958, Thiokol Chemical Corporation announces its jump belt – a tank of pressurised nitrogen gas with two nozzles. Releasing the gas through the nozzles generates brief upward thrust, allowing the wearer to leap several metres into the air.

Bell Rocket Belt
This hydrogen peroxide-powered flying machine is developed for the US Army in 1960. When hydrogen peroxide is passed through a silver catalyst it decomposes to superheated steam and oxygen, allowing about 20 seconds of flight.

Simplified Aid For EVA Rescue
NASA's SAFER is a small backpack developed in 1994 for the emergency rescue of stranded spacewalkers. It uses 24 fixed-position nitrogen thrusters for propulsion, but holds limited fuel so can only be used for short periods.

Bell RB2000
This updated version of the original hydrogen peroxide rocket belt is lighter, can carry more fuel and can remain airborne for 30 seconds – a full nine seconds longer than its predecessor.

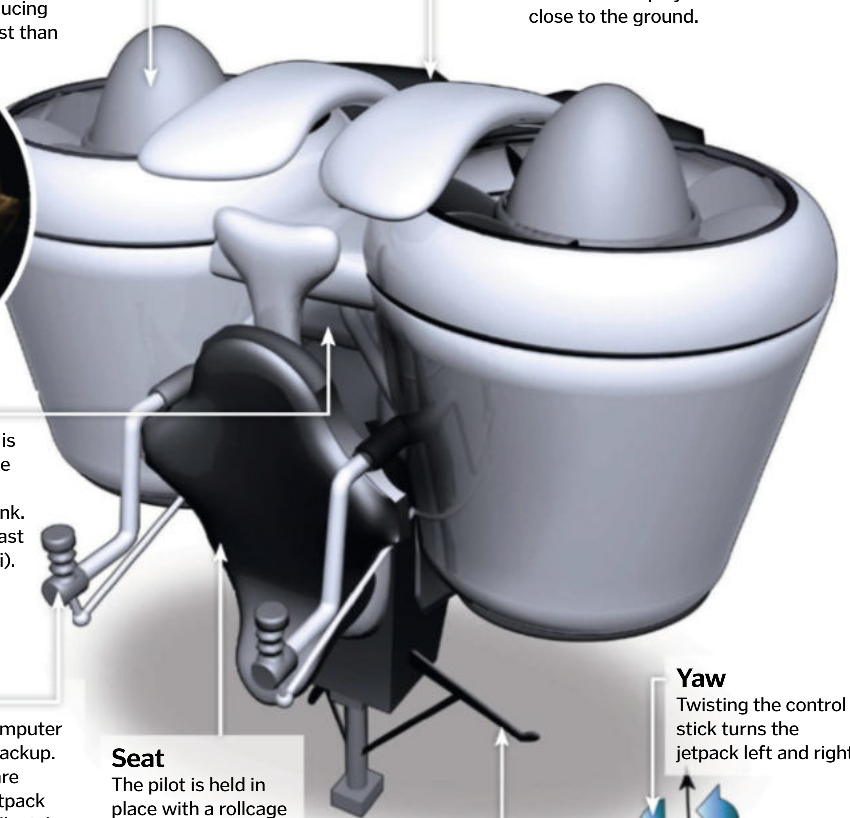
THE STATS MARTIN JETPACK

HEIGHT	2.2m
MAX SPEED	74km/h
WEIGHT	180kg
FLIGHT TIME	30mins
FUEL CAPACITY	45l
CRUISE SPEED	56km/h

DID YOU KNOW? Jetpacks are expensive – none of the models currently available cost less than £60,000 ($100,000)

The Martin Jetpack uncovered

We highlight the key components that make up the first commercial jetpack



Twin ducted fans
The sharp fan blades are mounted inside ducts, shielding the wearer and producing more static thrust than a propeller.

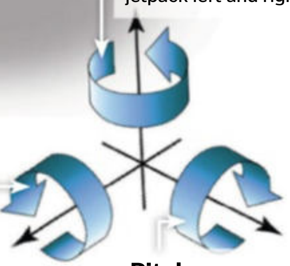
Emergency parachute
The jetpack contains a ballistic parachute, which opens rapidly and can be deployed close to the ground.

Fuel tank
Petroleum fuel is held in a 45-litre Kevlar and carbon-fibre tank. It's enough to last for 30km (19mi).

Controls
An on-board computer provides pilot backup. If the controls are released, the jetpack will automatically right itself and hover at its current altitude.

Seat
The pilot is held in place with a rollcage and arm restraints.

Landing legs
The frame is made from composite materials for strength and flexibility, absorbing shock as the jetpack touches down.



Yaw
Twisting the control stick turns the jetpack left and right.

Roll
Tilting the stick left or right rolls the jetpack to the side.

Pitch
Moving the control stick backward or forward pitches the jetpack up or down.

Building jetpacks

Martin Aircraft's CEO Peter Coker talks about the Martin Jetpack and the future of personal flight

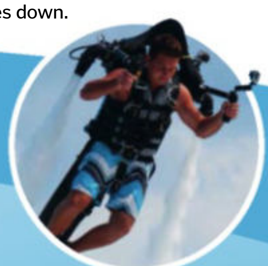
What are the greatest challenges when it comes to manufacturing a jetpack?
Peter Coker: There are a number of challenges in building a jetpack. They include the design of a flight control system, the duct technology and the power-to-weight ratio of an engine.

What are the contingencies if something goes wrong in the air?
PC: The aircraft has been designed with safety in mind. First, reliability is an important element. However, should something go wrong there is a ballistic parachute that is effective down to very low heights. The undercarriage has been designed to sustain a drop from specific heights and the pilot is partly surrounded by a carbon-fibre module, which provides a certain amount of personal protection. Future safety features are being considered for later models.

Why has it taken so long to get to this stage?
PC: Glenn Martin started his research into the jetpack in 1981, working from his garage. In 1988 he formed GNM Ltd and in 2008 the company was renamed the Martin Aircraft Company. We are now looking to commercialise the latest prototype so it has been 33 years in development. Jetpack theory is not simple, as shown by the time it has taken to develop the Martin Jetpack [to its current stage].

Is personal flight going to revolutionise how we get around in the future?
PC: Regulations will probably restrict it initially to that similar to an ultralite or microlite aircraft but when 'highways in the sky' are adopted by countries the full potential of the jetpack as a mode of transport can be fully realised.

Are there plans to develop other jet vehicles?
PC: Martin Aircraft Company has a full R&D team that continues to expand the capabilities of the jetpack. Our jetpack can be either manned or unmanned and therefore has substantial utility in the commercial environment as well as being a personal vehicle in the future.



Jet wing
The first jet wing, developed by Swiss pilot Yves Rossy in 2006, consists of a 2m (6.6ft) rigid wing with four jet turbines. It is manoeuvred entirely by the pilot's body and has an average speed of 200km/h (124mph).

JetLev
The first water-powered jetpack is developed in 2008 and arrives on the market in 2012. Water is supplied through a flexible hose, offering extended flight time but tethering the jetpack to the water, so altitude is limited.

Martin Jetpack
Planned for release in 2015, this ducted fan-based craft is more of a personal helicopter than a jetpack. But it is perhaps the most practical development so far for everyday use. Using a custom V4 engine, the Martin Jetpack can exceed altitudes of 900m (3,000ft).

"Pilots are kitted out in fire-retardant clothing and wear ear defenders to muffle the engine roar"

respectable flight time of half an hour, allowing the pilot to travel distances of up to 30 kilometres (19 miles) without needing to refuel. Interestingly, in unmanned testing, the Martin Jetpack has been able to reach altitudes of over 1,500 metres (5,000 feet).

Designing a jetpack is one thing, but ensuring that it's safe to fly poses a whole new set of challenges. Jetpack flight-testing begins with crash test dummies and short, low-altitude flights. Starting with bunny hops, the prototype flying machine is gradually refined and stabilised until it is able to take off safely. Once airborne, the test vehicle is flown via remote control and constrained by a ground-based tether, preventing any unexpected climb in altitude if the pilot loses control.

If the jetpack passes these initial tests, tethered manned flights are then performed, allowing human operation to be tried in a safe environment. Full-scale testing can then begin at higher altitudes and crash test dummies are used once again as the technology is refined. Higher-altitude testing also allows for any safety features to be trialled. The potential risks of flying a jetpack are high; the fuel is highly flammable, and an engine failure in midair could have catastrophic consequences.

Modern interpretations of the jetpack are built using high-tech composite materials and are packed with safety features. During flight, pilots are kitted out in fire-retardant clothing and wear ear defenders to muffle the engine roar. The Martin Jetpack is about as loud as standing in heavy traffic (around 95 decibels), although this is a significant improvement over the rocket belt, which generated a deafening 130 decibels – equivalent to a pneumatic drill!

The flying machines themselves are also fitted with parachutes; for the jet wing this is necessary to land, while for the Martin Jetpack, it is used as an emergency backup. The equipment is typically designed to be buoyant, ensuring the pilot is not dragged underwater should the jetpack land in water.

Despite the progress over the last few years, there are still several limitations that stand in the way of a jetpack resembling the kind described by science fiction. Jet fuel is heavy and expensive and, although ducted fans provide more efficient fuel consumption, at the moment they are much larger than the compact backpack most of us envisage.

Freedom of movement is a problem and the large duct casings that house the fans on the Martin Jetpack restrict its ability to move

Jetpacks in space

The fundamental barrier to jetpack success on Earth is gravity, but in space, astronauts are able to manoeuvre using little more than nitrogen gas. The Manned Manoeuvring Unit (MMU) and the Simplified Aid For EVA Rescue (SAFER) allow astronauts to perform untethered spacewalks. Depending on the input from the control panel, pressurised gas is channelled through any of 24 individual nozzle thrusters, allowing the jetpack to roll, twist and accelerate through space. They are even capable of automatically maintaining their position and orientation.

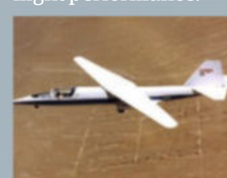
Four more pioneering aircraft

Ornithopter
Leonardo da Vinci designed a bird-like flying machine known as an ornithopter. It's unknown if he ever constructed his sketch, but a heavily adapted modern version, the Snowbird, is capable of flight.

'Bat' monoplane
In 1890 French engineer Clément Ader invented a steam-powered aircraft 13 years before the Wright brothers' first flight. It could only fly just off the ground and for a distance of around 50m (160ft).

Giffard dirigible
The powered airship was invented by French engineer Henri Giffard in 1852. This lighter-than-air craft was filled with hydrogen, propelled by a steam engine and steered using a sail-like rudder.

NASA AD-1
This unusual aircraft, first flown by NASA in 1979, proved that aircraft wings could be pivoted in-flight and that, at high speeds, turning the wings reduces drag and improves flight performance.



42.2km

LONGEST-EVER JETPACK FLIGHT

In 2012, Dean O'Malley travelled 42.2km (26.2mi) from Newport Beach to Catalina Island in the USA. The flight took just under five hours and was completed using a JetLev hydro jetpack.

DID YOU KNOW? *In the 1965 movie Thunderball James Bond uses a Bell Rocket Belt to escape from his assailants*

'Jetman' Yves Rossy flying over Rio de Janeiro in 2012 before landing on Copacabana Beach

Crafty comparison

How do these flying phenomena measure up?

JETPACK

Max speed: 74km/h (46mph)
Max altitude: 1,524m (5,000ft)
Max range: 30km (18.6mi)

JUMBO JET

Max speed: 988km/h (614mph)
Max altitude: 13,716m (45,000ft)
Max range: 13,450km (8,357mi)

HELICOPTER

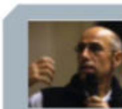
Max speed: 472km/h (293mph)
Max altitude: 7,620m (25,000ft)
Max range: 600km (373mi)

HOT-AIR BALLOON

Max speed: 28km/h (17mph)
Max altitude: 21,031m (69,000ft)
Max range: 10,783km (6,700mi)

GOLDEN EAGLE

Max speed: 190km/h (118mph)
Max altitude: 3,600m (11,811ft)
Max range: 4,800km (2,983mi)



Talking with Jetman

Yves Rossy has become the most famous jetpack pilot in the world – he talks to HIW about his passion

What inspired you to develop the jet wing?
Yves Rossy: I became a fighter pilot and then a captain for Swiss International Airlines. I had the idea to build a wing after discovering skydiving when I was 30. I enjoyed it and wanted to keep the same feeling, but with a real flight instead of a fall. I built this wing to make my dream a reality: to fly like a bird.

At the start, I could only glide. The next step was to motorise the wing, so I went to JetCat in Germany, world leader in model jet technology, and as my first and most important sponsor they made it possible to add power and engines.

How has the wing evolved over time?
YR: The very first one was an inflatable wing, which through trial and error I have modified into a solid wing. I have developed about 15 wings over the last 16 years. I have been working on this prototype (the one with four engines) for more than three years and I never stop trying to improve it. A big step forward was achieved after wind tunnel tests with RUAG Aerospace in 2008. A new shape was developed and a new wing was built by their team, improving stability and agility as well as lowering weight, leading to the current wing I now have on my back.

What does it feel like to fly with such minimal equipment strapped to you?
YR: Flying with the jet wing is an unreal feeling, because normally you have a big thing – a plane – around you. When I strap this little wing on, I have the feeling of being a bird. When you go out of the aeroplane you are almost naked… you have the feeling you're flying. And that's the nearest thing to the dream. You have no machine around you. You are just in the elements.

What are your future plans for the jet wing?
YR: My first aim is to keep optimising my wing. I wish to create a new prototype with more powerful engines that will give me the freedom to fly in three dimensions. The idea is to have as much thrust as weight. That would be total freedom. I want to share my invention so we can eventually fly in formation with several wings. After that, I want to explore all the potential the wing has, because it's enormous. I have gone down this road and I don't want to stop.

What's the scariest moment you have experienced while flying?
YR: I must have dropped the wing about 20 times! Luckily, every time it has been okay and I've let the wing go to become a normal parachutist. My wing also has its own parachute. These problems have already happened and they will certainly continue to occur.

How close do you think we are to mainstream personal flight?
YR: I hope we are not too far – my objective will be to share my passion.

"Aviation authorities haven't had to deal with jetpacks, so no specific regulations are currently in place"

forward and backward at high speed. Yves Rossy's jet wing is much more responsive, but this comes at the cost of not being able to take off and land without a helicopter and a parachute, respectively, though this is something Rossy is looking to address, with research into taking off from the ground.

Despite not quite hitting the benchmark set by fictional jetpacks, the new technology has huge potential. The military, search-and-rescue teams and emergency services in several countries have expressed interest in the Martin Jetpack. It is quick, has a reasonable range and can reach areas inaccessible from the ground. The units can also be controlled remotely, allowing jetpacks to enter areas too dangerous for humans, or to act as rescue drones, picking up a passenger and returning them to safety.

Ultimately though, the hope is that the Martin Jetpack will also be used for fun. Until now, aviation authorities across the world haven't had to deal with jetpacks, so no specific regulations are currently in place. It is therefore up to local aviation authorities to set their own rules when the need arises. In New Zealand, manned test flights of the prototype Martin Jetpack have been approved, but there are heavy restrictions. The pilot must have a licence and can't fly over six metres (20 feet) above the ground, or 7.6 metres (25 feet) above water.

The finished jetpack, scheduled to hit the market by 2015, is expected to cost upward of £90,000 ($150,000). Martin Jetpack's developers hope to avoid mandatory licences by designing the jetpack to match the existing Federal Aviation Authority ultralight standards.

So while Buck Rogers' jetpack is not quite here yet, engineers are bringing the personal aviation dream ever closer to reality.


Yves Rossy flying alongside WWII fighter planes; be sure to check out the video on our website!


Looking to improve on the jetpacks built by Bell in the Sixties Jetpack International has been developing its own machines since 2003, regularly appearing at indoor and outdoor events

The Martin Jetpack during a test flight in New Zealand

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

See Jetman flying alongside a Spitfire now!

www.howitworksdaily.com

DID YOU KNOW? *The first jetpack tests were carried out during WWII and were as simple as strapping rockets to crash test dummies*

Flying with water jets

JetLev uses water jets to provide lift. Water is pumped through a reinforced nylon pressure pipe to the jetpack at a rate of 4,550 litres (1,000 gallons) per minute. The water is directed downward and shoots out of two nozzles near the pilot's shoulders at a pressure of 4.2 kilograms per square centimetre (60 pounds per square inch). This might sound surprisingly little, given that the average pressure washer shoots water jets at over 127 kilograms per square centimetre (1,800 pounds per square inch), but it is sufficient to lift both jetpack and pilot to heights of up to 8.5 metres (28 feet).

In order to achieve such a high rate of water flow, the JetLev must be permanently attached to a pump and a water source by a hose, limiting its mobility slightly, but also preventing the pilot from reaching dangerous altitudes where the water jets would be insufficient to maintain control.

Throttles
Handheld controls allow the angle of the jets to be changed and the pilot shifts their weight to steer.

Flight ceiling
The water supply tube acts as a tether, preventing the jetpack flying too high, or over land.

Water jets
Two pressurised jets of water generate an upward thrust of some 2,220N (500lbf).

Quick-release harness
In an emergency, the jetpack can be easily removed by undoing the harness clip.

Water hose
Water is pumped to the jetpack in high volumes and at low pressure through a reinforced, flexible nylon tube.

> "The hybrid electric plane can engage power from the fuel-powered rotary engine and the electric system"

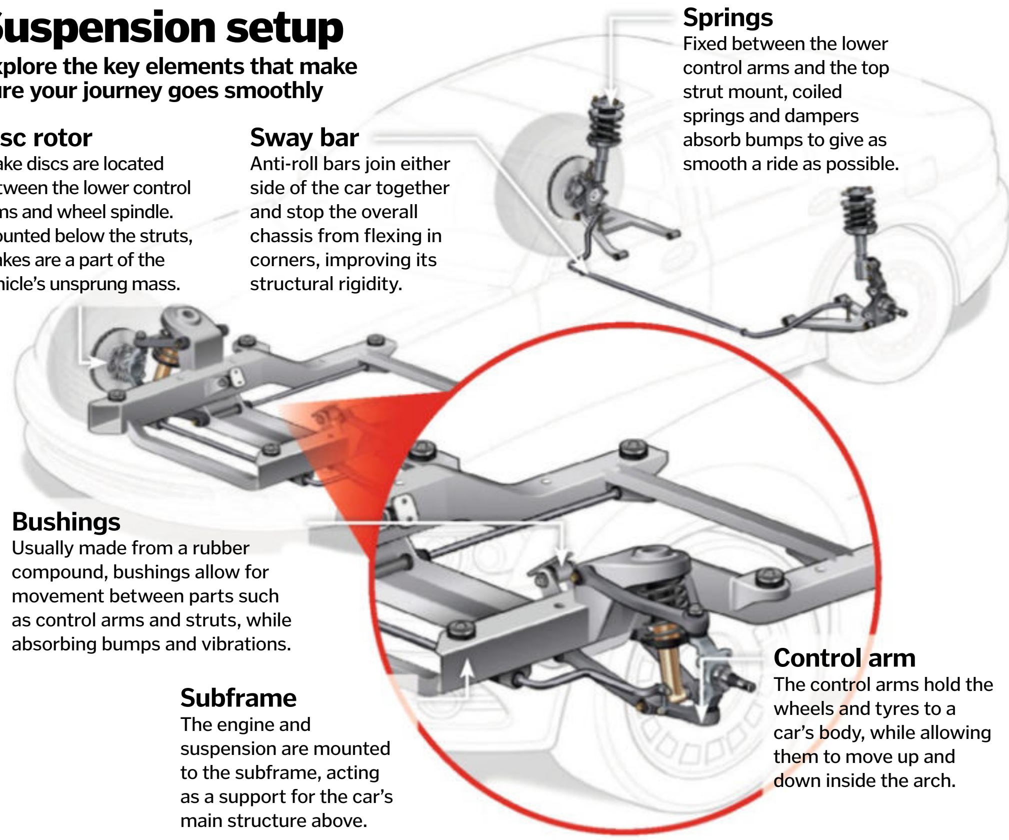
How suspension works

More than just springs, a car's suspension ties together several key systems

The suspension is one of the most advanced systems on a modern-day vehicle, helping to maximise friction between the car's tyres and the road surface and ensuring the driver and passengers enjoy as comfortable a journey as possible. The main element here is the four suspension struts, with one in each corner of the vehicle. These consist of coil springs, which absorb any irregularities in the road surface by compressing and expanding. Shock absorbers in the strut control this spring motion by converting their kinetic energy into heat via hydraulic fluid. This stops the springs from continually bouncing a vehicle as it travels along the road. Struts are fixed to the chassis via control arms, which pivot at either end to allow movement of the wheels within the wheel arch as the suspension compresses and expands, without the need for the whole vehicle to be pushed up and down along with them. Anti-roll bars and strut braces connect either side of the car together to ensure the vehicle remains sturdy when cornering, reducing flex, while bushings underneath the car ensure that any further vibrations from the road surface are cancelled out.

Suspension setup

Explore the key elements that make sure your journey goes smoothly



The rapid development in greener vehicles such as hybrid electric planes looks set to redefine the future of air travel

Hybrid aeroplanes

New eco technologies could lead to a greener and more sustainable aviation industry

Aeroplanes have long been powered by engines relying on jet fuel. However, with Earth's oil reserves running low, the aviation industry has to invest in new sustainable technologies to power aircraft. One example is the DA36 E-Star 2, which melds a fuel-powered engine (ie a Wankel rotary unit) to an electric system powered by rechargeable batteries.

Similar to a contemporary hybrid car, the hybrid electric plane can engage power from the fuel-powered rotary engine and the electric system, or it can switch the rotary engine off and run purely on electric power. Further, the batteries supplying the electric power can be recharged in-flight.

Hybrid technology offers many new advantages and could pave the way for a greener future for aviation. Hybrid technology means fuel consumption is cut drastically and the rechargeable batteries provide planes such as the DA36 E-Star 2 with a sustainable energy source. Fewer engines per plane (some aircraft have up to four) will also ensure a significant reduction in fuel emissions.

STRANGE BUT TRUE
A KNOTTY AFFAIR

What did Alexander the Great do with the Gordian knot?

A Tied it B Added another knot C Cut it

Answer:
Tasked with the challenge of untying the fabled Gordian knot, an intricate knot made of cornel bark which was supposedly impossible to untie, Alexander the Great merely drew his blade and sliced the knot in two, ending a decades-old challenge in one fell swoop.

DID YOU KNOW? *A wading bird called a knot visits UK estuaries in the winter before returning to the Arctic to breed*

Sailing knots untangled

Why knots have been so important to the boating world throughout history

Before modern metal fasteners and cords were invented, the only way to secure sails, equipment and supplies on board an ocean-going vessel was through the age-old technique of knot tying. Indeed, due to Earth's wild oceans, knot tying became a vital skill of any mariner, with several types needing to be mastered before any captain would take them on. Today, while more convenient transport has taken over mainstream marine travel, hobbyist and competition sailors still use knots alongside more modern fasteners on their vessels.

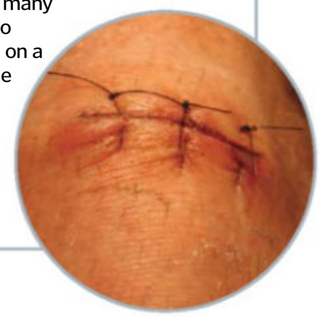
There are many families and types of knots, but in a sailing context the hitch, loop and bend groups are the most important, with individual knots such as the sheet bend, bowline and clove hitch used most frequently.

With the age of sail's reliance on the wind for propulsion, ensuring a vessel's sails were rigged properly and with maximum efficiency – ie ensuring the sails are as taut/slack as possible when catching the wind – was incredibly important, so core knots were also partnered with more common varieties such as the shortening sheepshank and overhand stopper.

After all, if a sailor can't even properly secure a vessel to the dock – still typically done today with a mooring hitch – then they might not even have a ship to come back to!

Where else do knots come in handy?

While sailing is probably the most widely used application for knots, they are an incredibly useful tool in many fields, ranging from camping to climbing and beyond. Until very recently, knots were even a key part of surgery, with examples such as the surgeon's knot used to maintain tension on a wound or body tissues during an operation. Of course, many wounds and cuts are also closed with knots, albeit on a small scale, with a needle and thread (called a suture). The first recorded mention of knots used in surgery stems from 'father of medicine' Hippocrates.



Know your knots

Check out eight of the most common sailing knots with this guide

1 Clove hitch
This is a crossing and binding knot that can be easily loosened and adjusted by feeding in rope from either end.

2 Bowline
An ancient method of forming a fixed loop at the end of a piece of rope. It is also known as the 'king of knots'.

3 Cleat hitch
As its name suggests, this is a sailing knot used to tie rope to a cleat – a horn-shaped piece of metal or wood around which ropes can be secured on deck.

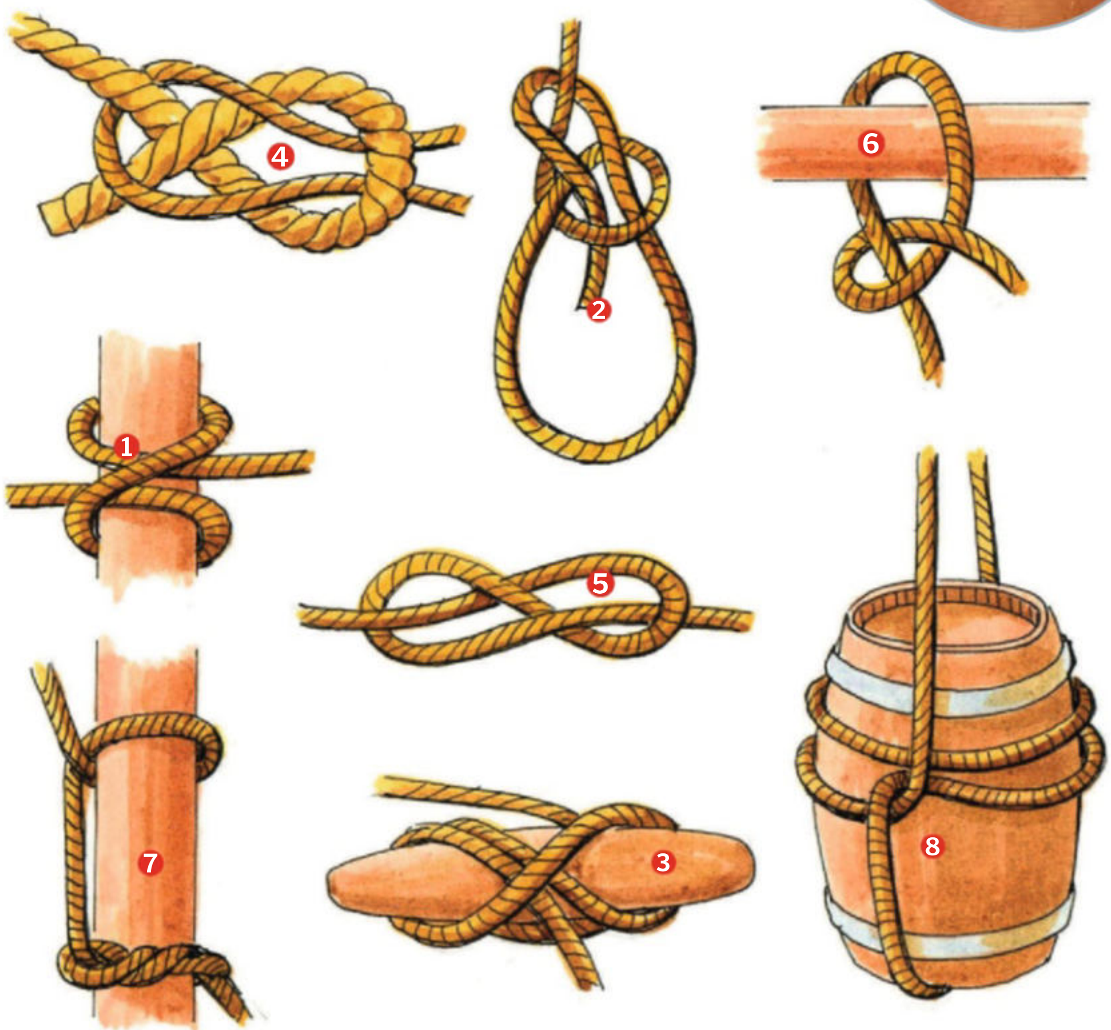
4 Sheet bend
Another foundation knot, used to join two pieces of rope together. As with the bowline, it's quick and easy to tie.

5 Stopper knot
One of the most basic sailing knots, it prevents the end of a rope from unravelling or slipping through another knot.

6 Half hitch
A simple but common knot, it can be used as a fastening knot but is often done for decoration or as part of more complex knots.

7 Timber hitch
A primary technique for fastening a length of rope to a pole that's often combined with a half hitch. It's ideal for sailing and camping.

8 Barrel hitch
Used to tie rope around heavy curved objects like barrels, making it easier to hoist them on and off board.



"Although fire trucks can weigh 15 tons or more, they have compensated by installing turbocharged engines"

Fire engines uncovered

Learn why putting out massive blazes and saving lives is all part of the day job for these superhero vehicles

Fire engines truly are incredible machines. They have evolved to tame one of nature's elemental forces – the hot, burning one – achieving this by mastering another – the cool, liquid one. Their mastery of water, along with the crew that operate them, has saved countless properties, areas of wilderness and human lives over the centuries.

These vehicles come in all shapes and sizes tailored for different kinds of emergencies, both in urban and rural environments. A typical fire engine needs to perform three primary duties: get officers to the scene as fast as possible, carry all the essential equipment and serve as a portable water pump and sometimes reservoir.

The greatest challenge to response time are its other two main roles; all that water and equipment on board are not conducive to speed. Although fire trucks can weigh 15 tons or more, they have compensated for this by installing turbocharged engines and by keeping a compact form to negotiate traffic and narrow roads.

No space is wasted, with compartments lining the walls packed with all the tools a firefighter might possibly need. One of the most important pieces of equipment, however, is too big to fit in any compartment. Telescopic ladders and hydraulic platforms sit on the roof and are vital for accessing the upper storeys of burning buildings as well as providing an elevated position to survey and extinguish fires.

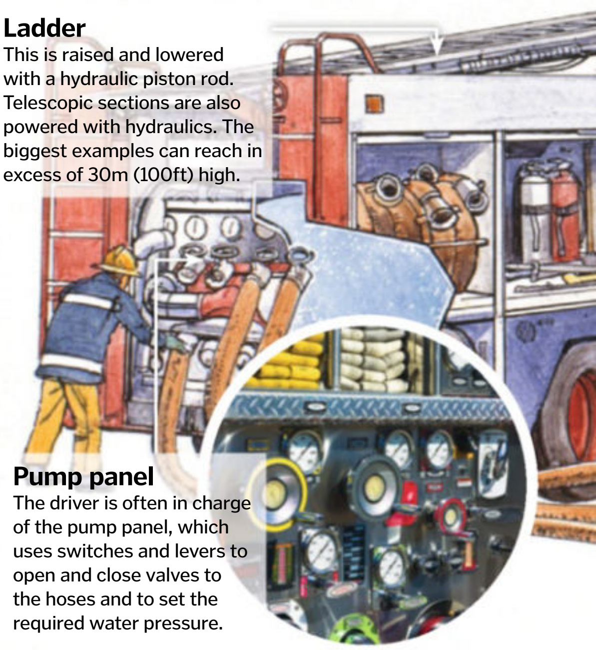
But a fire engine's most fundamental weapon is water. While some fire trucks have the capacity to hold thousands of litres in a central tank, others tap into nearby sources like a hydrant or a lake. The water is fed into a centrifugal pump at the heart of the vehicle, where a fast-spinning impeller forces it back out at great pressure.

Numerous colour-coded hoses draw from this single pump, controlled by a panel of switches and levers. Depending on the pump's size and the number of lines, a fire can be deluged with as much as 10,000 litres (2,640 gallons) per minute, though typically the flow is around half this rate.

These days special foam is often mixed with the water prior to leaving the fire engine because the way it clings to burning surfaces drastically cuts the amount of time it takes to put out a blaze.

Fire trucks on the job

A closer look at how the major technology on board these vehicles is used in an emergency



Ladder

This is raised and lowered with a hydraulic piston rod. Telescopic sections are also powered with hydraulics. The biggest examples can reach in excess of 30m (100ft) high.

Pump panel

The driver is often in charge of the pump panel, which uses switches and levers to open and close valves to the hoses and to set the required water pressure.

Fighting fire over time

Firefighting has a longer history than you might think – here are some of the biggest milestones in the war against conflagrations

100 BCE
Marcus Crassus forms the first fire brigade in Rome. Only the wealthy can afford his rates.

27 BCE
Emperor Augustus puts together the Vigiles for fighting crime and fires, but their techniques enjoy only limited success.

1500s CE
Hand pumps are used to put out small fires, but only have a short range so aren't very effective against bigger blazes.

1666
After the Great Fire of London, insurance companies begin offering personal protection schemes.

1672
Jan van der Heyden from the Netherlands invents the first fire hose made out of leather and brass.

1. LAND

Airport crash tender
Designed to deal with fires at airports. They include chemicals like Purple-K that can put out jet fuel quicker than water alone.

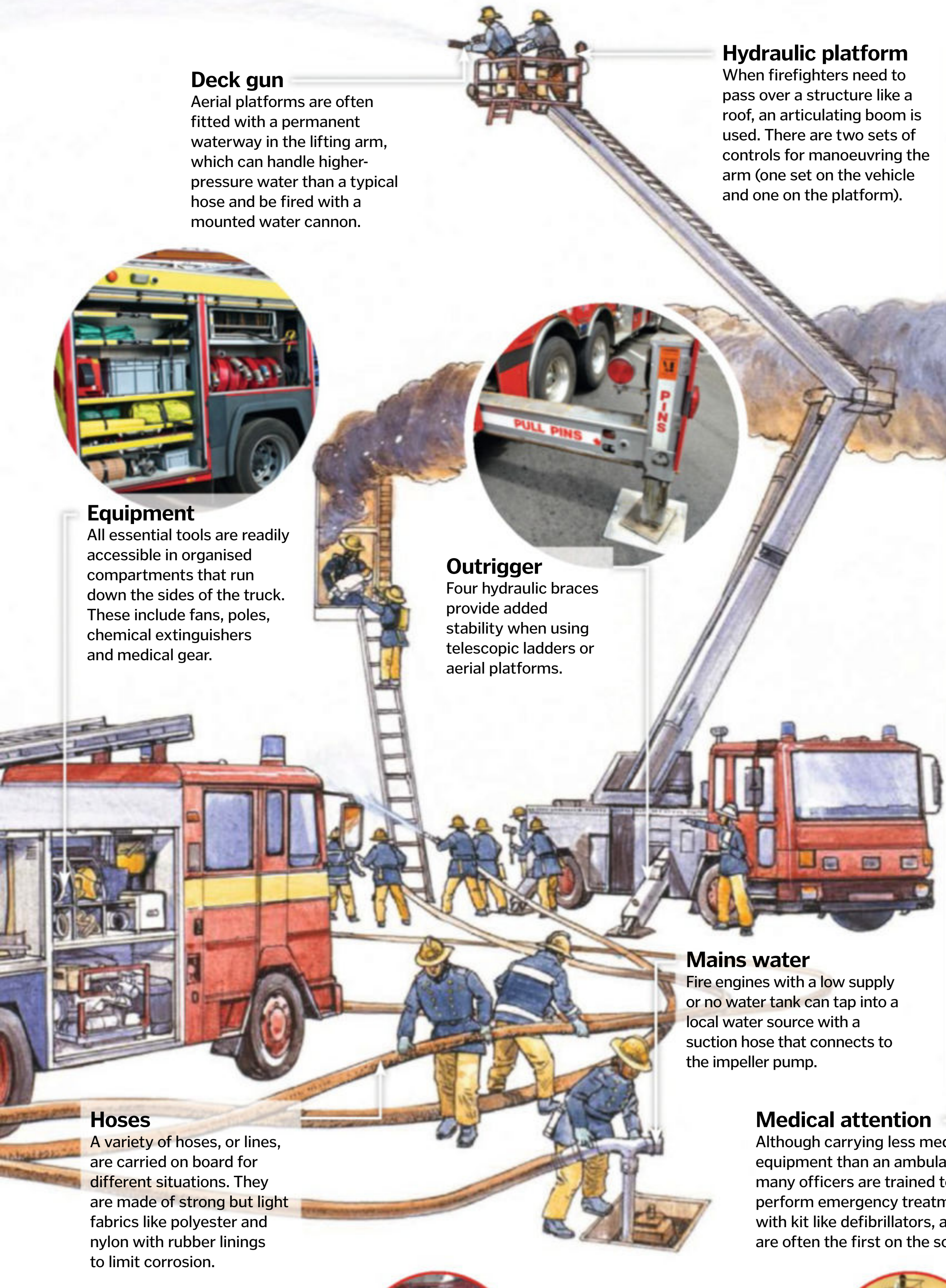
2. SEA

Fireboat
Perfect for putting out fires on vessels at sea, they're fitted with a series of pumps that supply cannons directly from the ocean so they never run out of water.

3. AIR

Helitanker
They may not have the capacity of firefighting planes, but helitankers are quicker and more manoeuvrable, making them well suited to extinguishing wildfires.

DID YOU KNOW? *William I decreed house fires should be put out at night, using a 'couvre feu' fire cover (hence 'curfew' in English)*



Deck gun
Aerial platforms are often fitted with a permanent waterway in the lifting arm, which can handle higher-pressure water than a typical hose and be fired with a mounted water cannon.

Hydraulic platform
When firefighters need to pass over a structure like a roof, an articulating boom is used. There are two sets of controls for manoeuvring the arm (one set on the vehicle and one on the platform).

Equipment
All essential tools are readily accessible in organised compartments that run down the sides of the truck. These include fans, poles, chemical extinguishers and medical gear.

Outrigger
Four hydraulic braces provide added stability when using telescopic ladders or aerial platforms.

Mains water
Fire engines with a low supply or no water tank can tap into a local water source with a suction hose that connects to the impeller pump.

Hoses
A variety of hoses, or lines, are carried on board for different situations. They are made of strong but light fabrics like polyester and nylon with rubber linings to limit corrosion.

Dennis Sabre fire engine by numbers

5
Number of crew in cab

1,800l
Capacity of water the tank can hold

13 tons
Total weight of vehicle

70mm
Diameter of widest hose

2,500l/min
Flow rate delivered by pump

13.5m
Length of longest ladder

Meet the crew
A fire engine might be an impressive machine, but it would be nothing without its crew. While the number of firefighters varies between vehicles, the minimum tends to be three. Roles include the driver (who often operates the pump too), an officer-in-charge (OIC) to co-ordinate the team, an entry control officer who specialises in gaining access to blazing structures, and one or two officers to operate hoses and don breathing apparatus should there be need to enter the building. As well as learning to 'read a fire' and put out conflagrations as quickly and safely as possible, firefighters are trained in emergency medicine and hazardous materials, which can mean the difference between life and death.

Medical attention
Although carrying less medical equipment than an ambulance, many officers are trained to perform emergency treatment with kit like defibrillators, as they are often the first on the scene.

1690
John Lofting patents the 'Sucking Worm Engine' to much acclaim, greatly increasing the range of water from the hose.

1720s
Taking inspiration from Lofting's design, the Little Newsham engine can pump around 605l (160ga) of water per minute up to 50m (165ft).

1733
In a groundbreaking departure from tradition, France decides a fire service should be free to all.

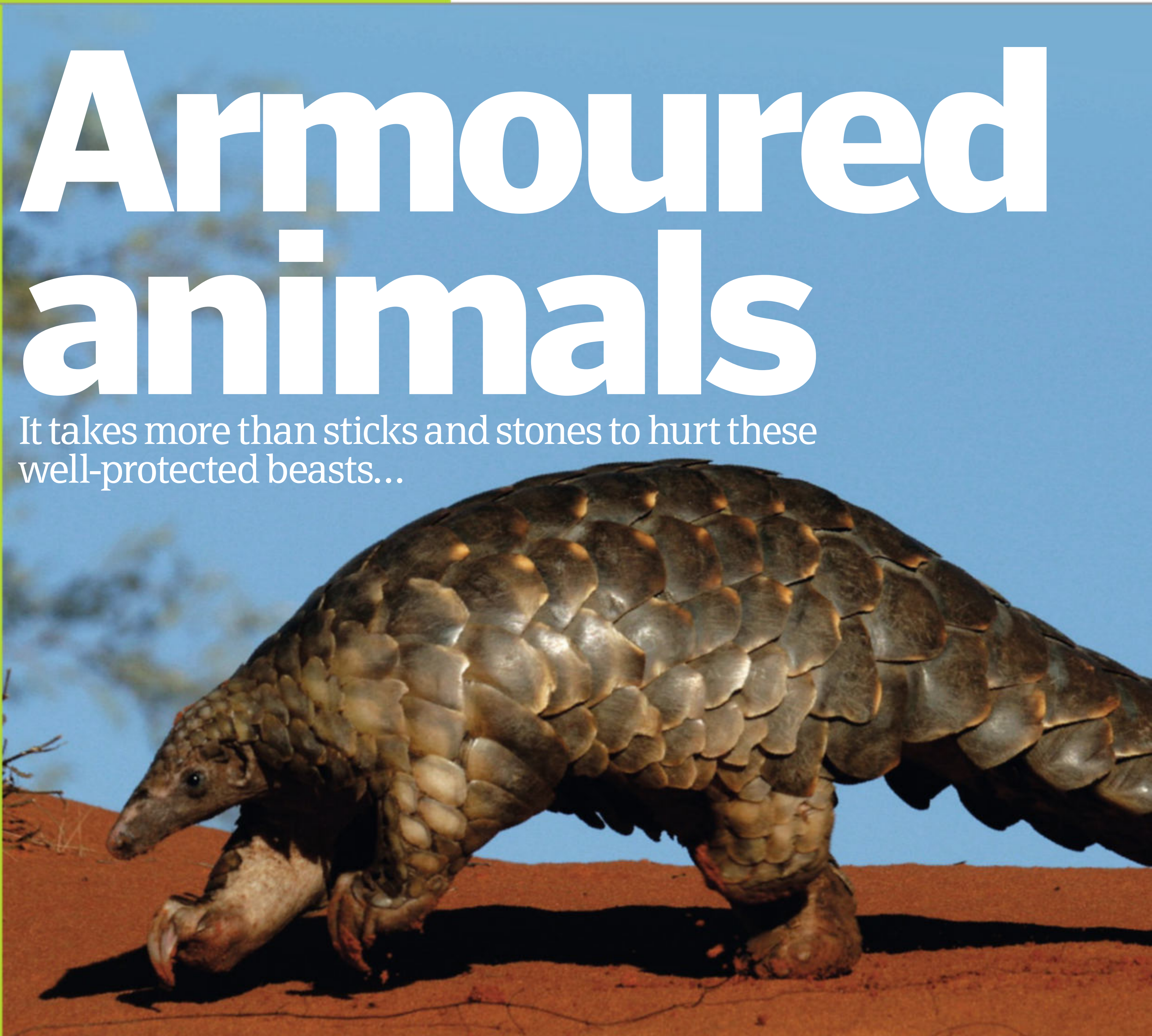
1824
James Braidwood establishes the world's first organised municipal fire brigade in Edinburgh, later becoming the first director of the London Fire Engine Establishment.

1853
Cincinnati in Ohio is the first city in the USA to set up its own professional fire department.

1905
The internal combustion engine is used to move the vehicle and power the water pump more efficiently than before.

Armoured animals

It takes more than sticks and stones to hurt these well-protected beasts…



Animals have used armour to protect themselves from predators for as long as there have been predators. There are heavily armoured trilobites in the fossil record from as far back as 540 million years ago, and natural selection drove the prey to evolve a tough skin. It's logical evolution. When something tried to bite them, the better-armoured ones were more likely to survive.

In a marine environment, weight is much less critical than on land so most invertebrates reinforce their exoskeletons with calcium carbonate extracted from the seawater, to make them literally harder. On land this would make movement almost impossible, so terrestrial armour plating needs to use lighter materials such as keratin and chitin, and assemble them in complex layered or honeycomb structures to keep them strong but flexible.

All armour is a trade-off between protection and restriction. Some armour can be put to more than one use; eg the devil lizard uses the tiny cracks between its armoured scales to wick up water from the desert dew. But the best kind of shield is the one that you can raise and lower at will. The blowfish is covered with sharp spines that would massively increase its drag when swimming if they stuck out all the time. So it keeps them folded back most of the time and, when danger threatens, it takes a deep breath of water to inflate its body and push out the spines. Most animals don't have armour over their entire body either; it's easier to just protect the

STRANGE BUT TRUE
RIVER CROSSING

How do armadillos normally cross a river?

A By swimming B By walking C By crocodile

Answer:
The armadillo's heavy shell means it normally sinks in water. But armadillos can hold their breath for up to six minutes, so they just walk along the bottom. For larger rivers they swallow air to inflate their stomach and float across.

DID YOU KNOW? *After moulting, a lobster will eat its own shell in order to regain lost calcium*

Natural plate mail

All reptiles have scaly skin, but crocodiles and their relatives have reinforced this with bony plates under the skin, called osteoderms, to provide extra protection along the back. Turtles and tortoises have taken this a step further by fusing the osteoderms into a rigid shell. A shell provides excellent protection from predators but it's very slow and heavy. When mammals evolved, they swapped scales for fur and lost their armour plating. But two strange animals – the armadillo and the pangolin – have since re-evolved their own version. Pangolins (pictured below) have overlapping scales like a pine cone. The scales are made of keratin and are a bit like a coat made of fingernails. Pangolins have scales running right down to the tip of their tail and when threatened, they will roll into a ball like a hedgehog. Armadillos have armour made of bone, with a layer of smaller keratin scales on top. The head, shoulders and rear each have a single fused piece of armour, but the middle has a concertina of armoured rings that allow the armadillo some flexibility. The three-banded armadillo is the only one able to roll completely up into a ball. The other species rely on a combination of armour and speed to escape.

exposed areas. For example, the cassowary bird has just a single bony plate on its head, to act as a crash helmet as it charges through its forest home's thick undergrowth.

Evolution is a natural arms race. Whatever defences one animal comes up with, there will be a predator that evolves a way around it. However, in order to pass your genes on to the next generation, you don't need to be completely invulnerable. You just need to be harder to eat than the guy next to you.

Spine power

Spines are a specialised form of hair. They are made from hollow tubes of keratin protein that taper into a thin point. Hedgehogs and porcupines both use spines as armour but the animals are not related. Hedgehog spines are short and firmly attached to the skin. The hedgehog simply rolls into a ball when threatened and hopes a predator will give up trying to find a way in. Porcupines are much more aggressive, with up to 30,000 spines that can be 10-20 centimetres (four to eight inches) long. They will actively charge at predators or swipe with their tails. The spines dislodge on contact and the tip expands with the body heat of the victim, trapping it there. North American porcupine spines even have barbs that will ratchet their way deeper into the body – moving several millimetres a day! Predators can die from the stab wound or starve to death because a mouthful of spines stops them eating.

A focus on quill anatomy

How porcupines control the release of their spiky self-defence

1 Quill shaft
A porcupine quill is hollow and much thicker than the root that anchors it to the skin, helping its release.

2 Skin
The root doesn't sit under the porcupine's skin; the skin surrounds it like a cup.

3 Guard spool
A ring of connective tissue stops the quill from being driven back into the porcupine's body.

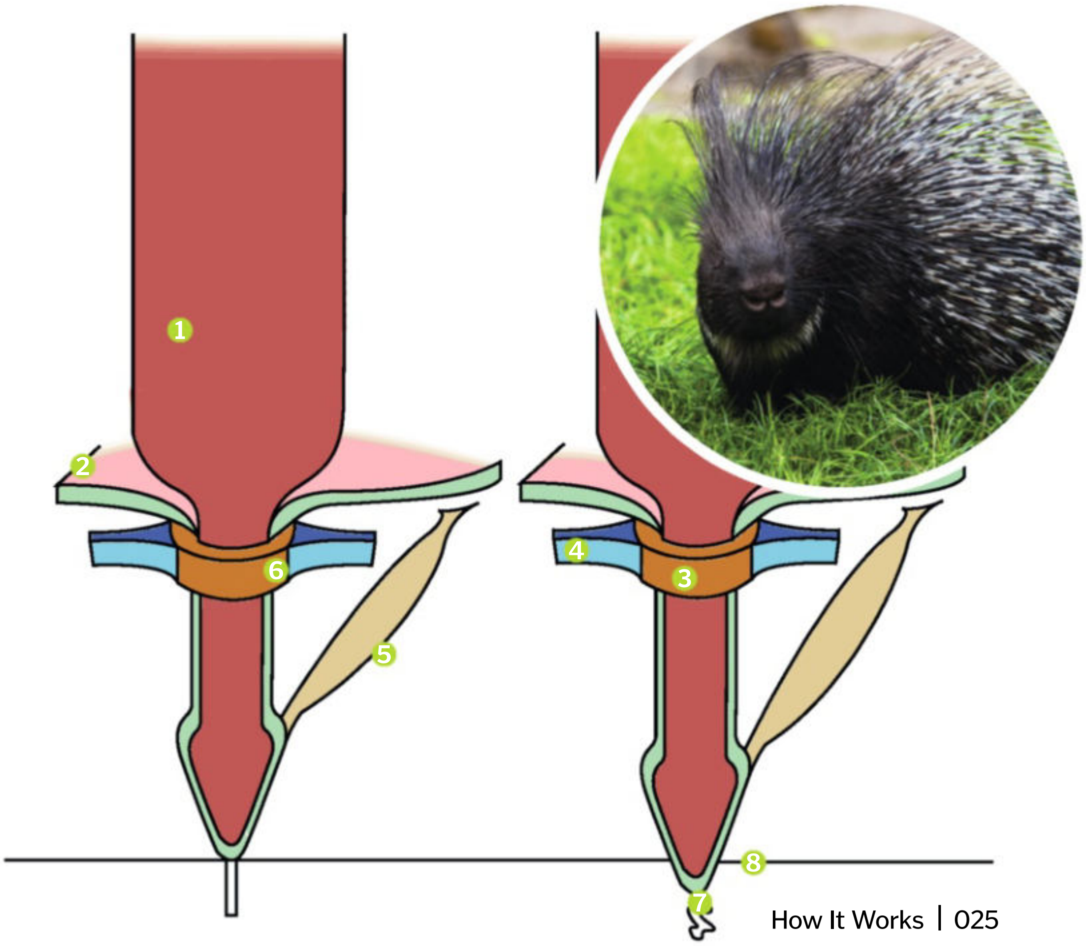
4 Transverse muscle
When the porcupine is alert, this muscle tenses to 'arm' the spine.

5 Piloerector muscle
The same muscles that raise the hairs on your arm when you're cold lift the porcupine's spines when threatened.

6 Safety on
With the transverse muscle relaxed, the guard spools can move up and down and the spines stay attached.

7 Fire!
As the muscle grips the spool, the spine tears the quill at the root, releasing it from the skin.

8 Retinaculum
Anchoring tissue holds the skin in place as the quill is pulled free.



> "Sharks have skin covered in overlapping scales called dermal denticles constructed like teeth"

Thick skin

Elephants are pachyderms. The name means 'thick skin' and elephants can have up to three-centimetre (1.2-inch)-thick skin on their back and around their trunk and legs. But the skin around an elephant's ears and chest can be as thin as paper so elephants are actually quite vulnerable to sunburn in certain areas.

The real champions of skin armour are whales and sharks. Sperm whales have a layer of blubber that can be 35 centimetres (13.8 inches) thick – the thickest skin of any animal. Blubber is a mixture of fat reinforced with collagen fibres and densely supplied with blood vessels. Its primary purpose is to provide insulation and buoyancy, but sperm whales hunt giant squid and the whale's blubber protects it from the squid's tentacles armed with hundreds of suction cups with saw-tooth cutting edges. Sharks, meanwhile, have skin covered in overlapping scales called dermal denticles that are constructed like teeth, complete with enamel and serrated cutting edges. This makes their skin almost bulletproof!

Like their thick-skinned relations, rhinos are pachyderms along with elephants and hippos

Colourful jewel beetle shells serve the dual purpose of protection and attracting mates

Extraordinary exoskeletons

An exoskeleton is more than just a piece of armour. It also provides the attachment points for the muscles, to give them something to pull against. Both insects and crustaceans use chitin as the main building material of their exoskeleton. Chitin is a polysaccharide, like starch or cellulose, but it performs the same role as the keratin protein in vertebrates. By itself, chitin is soft and pliable, but the chains are very strong and hard to snap. By arranging it into sheets with the fibres running in different directions, chitin forms a tough, tear-proof layer. That's plenty for small creatures like insects, but crustaceans take this process a step further by impregnating the weave of this chitin cloth with calcium carbonate. The result is a carapace as strong as stone but much less brittle. The biggest disadvantage of all exoskeletons is that they can't grow with the animal, so they must be shed periodically.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch hermit crabs fighting over a new shell

www.howitworksdaily.com

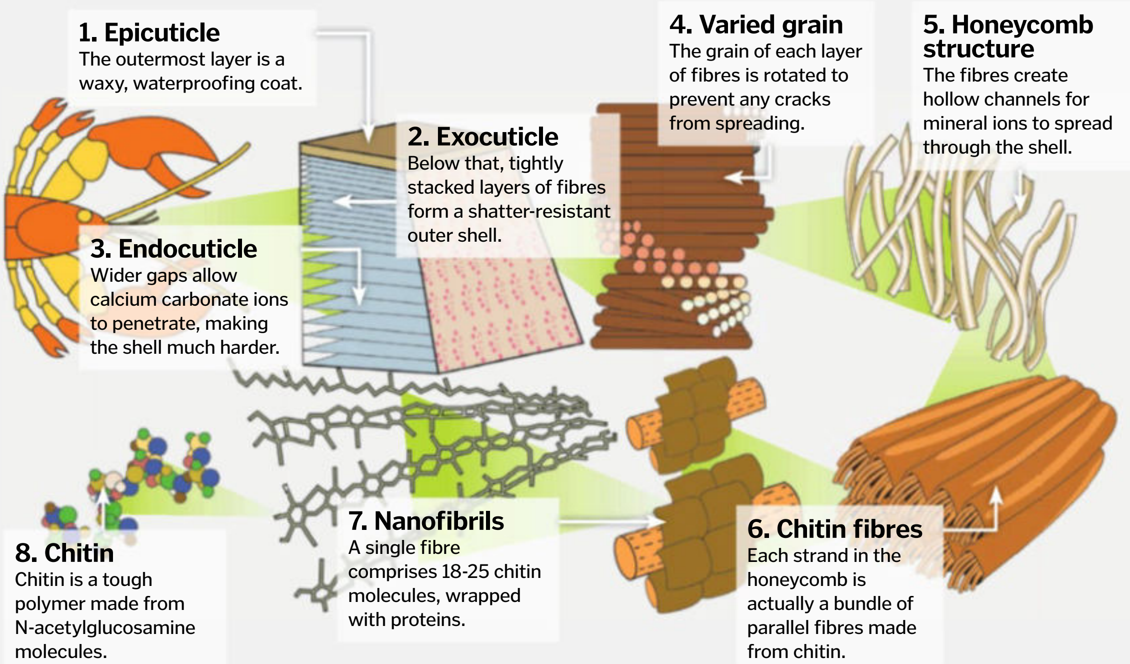
DID YOU KNOW? Microscopic serrations allow porcupine quills to puncture skin twice as easily as a hypodermic needle

Temporary shelter

Hermit crabs don't have shells of their own but their soft abdomen is curved in a spiral that makes it a snug fit for the shells of gastropod molluscs, like sea snails. They have to regularly upgrade to a larger shell as they grow but they save themselves the considerable metabolic cost of hardening their own exoskeleton. Some of the borrowed shells gain an extra layer of protection in the form of sea anemones that attach to the outside. The anemone feeds on scraps dropped by the crab and in return, its stinging tentacles keep predatory fish away. One species of hermit crab even uses colonies of encrusting coral-like bryozoans to extend the size of its shell. This clever subcontracting arrangement gives the crab the advantages of a living shell, without the expense of building it.

Why are lobster shells so strong?

See the components that make up a crustacean's armour, right down to the atomic level



Attack is the best defence

1 Golden poison frog

The most poisonous of the poison dart frogs and possibly the most poisonous animal of all. The alkaloid toxins on the skin of a single frog would be enough to kill you ten times over, if you ate one.

2 Giant squid

Rather than producing a cloud of ink as a smoke screen, the giant squid squirts a long thin blob that resembles the squid itself. Then it jets away, leaving the confused predator chasing shadows.

3 Skunk

Skunks secrete a foul-smelling mixture of thiols and thioacetates from their anal glands. If they are running away, they spray a mist that predators must run through, but can also shoot a directed stream from 3m (10ft) away.

4 Texas horned lizard

When threatened by coyotes, horned lizards raise the blood pressure around their eyes until they squirt a jet of blood mixed with irritating chemicals. The lizards can fire up to a third of their total blood volume this way.

5 Bombardier beetle

The bombardier beetle possesses the ultimate squirt defence, combining hydrogen peroxide and hydroquinone in a combustion chamber in its abdomen. Exploding on contact, they eject hot gas that can kill attacking insects and deter larger predators.

KEY DATES
CLONING OVER TIME

1894
Hans Driesch proves separated cells retain enough DNA data to create life.

1902
Physiologist Gottlieb Haberlandt (right) isolates a plant cell and attempts to culture it.

1922
Kolte and Robbins manage to create root and stem tips respectively from plant-tissue cultures.

1952
A viable frog embryo is successfully cloned from the embryo of a tadpole.

1996
Dolly the sheep is created, cloned by using a cell from an adult sheep.

DID YOU KNOW? *The first commercially cloned animal was a cat called Little Nicky. Born in 2004, it cost its owner £30,000 ($50,000)*

How are plants cloned?

Find out how we make identical copies of plants and what benefits this offers

The process of cloning plants has been used in agriculture for centuries, as communities split roots and took cuttings to efficiently create multiple plants.

Taking a cutting from near the top of a plant, placing it in moist soil and covering it will enable a new offspring to grow with the same genetic code as the parent from which it was taken. This method of cloning is very easy to do and is common among casual gardeners and industrial farmers alike. However, in more recent years the cloning of plants has made its way into the laboratory.

Responsible for that shift is Gottlieb Haberlandt, a German physiologist. At the beginning of the 20th century, he was the first to isolate a plant cell and then try to grow an exact replica of the parent. His attempt ultimately failed, but the experiment showed enough promise to convince others to follow in his footsteps. The likes of Hannig in 1904 and Kolte and Robbins in 1922 ran successful experiments in which they also cultured plant tissue to create new versions.

The main benefit of cloning flora is that growers are able to guarantee disease-free plants by cultivating cells from strong and healthy ones, leading to higher and more reliable crop yields. By taking cuttings from proven strains, a farmer can be sure his next generation of crops is equally successful.

Back inside the lab, the development of cloning through cultivating plant tissue allows for species to even be adapted and improved. However this genetic modification (ie GM crops) remains a controversial topic, as some experts argue we can't predict what the consequences of this human interference will be.

Plant cloning can be as basic as snipping off a stem from a begonia or as complex as growing a tomato plant in a solution of inorganic salts and yeast extract, but nevertheless the process by which you can create two plants out of one remains a triumph of natural science.

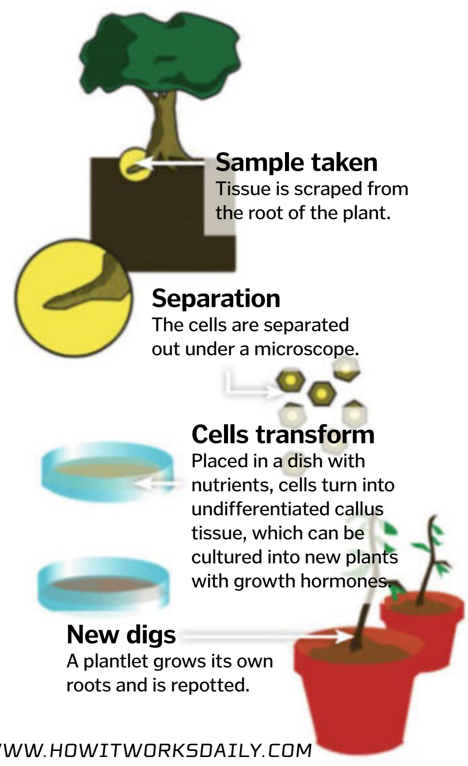
Dolly lived to be almost seven years old

What about animals?

Most of us are aware of Dolly the sheep, the first animal cloned from an adult cell, but artificial cloning dates back to the late-19th century. Hans Dreisch created two sea urchins by separating two urchin embryo cells from which two offspring grew, proving that DNA is not lost through separation. The next big development came in 1952 when a frog embryo was cloned by inserting the nucleus from a tadpole's embryo cell into an unfertilised frog egg cell. But the creation of Dolly in 1996, cloned using a mammary cell from an adult sheep, led to hopes that one day we might be cloned as well. There's still a while until a human can be replicated, but Dolly represented a huge leap forward in terms of cloning possibilities.

Plant duplication guide

Discover how plants can be cloned in the lab through the process of cell separation



Laboratory plant cloning is used for scientific research and to develop stronger strains

"In China, sandstorms and dunes from the advancing Gobi Desert swallow up entire villages"

How deserts grow

Discover why farmland across the planet is being swallowed at a terrifying rate by creeping sands…

Each year 0.2 per cent of usable farmland is lost from arid regions worldwide. That may not sound like a lot, but pressure on food and water resources is growing exponentially. Indeed, Earth's population is predicted to increase by a staggering 4 billion people by 2100.

Desertification occurs when farmland is overused in dry climates with fragile ecosystems already vulnerable to drought. Many affected areas are home to the poorest people in the world.

Livestock overgraze grass and wear away earth with their hooves, while intensive arable farming depletes nutrients in the soil. Toxic salts build up and farmland becomes waterlogged when fields are overwatered by irrigation. Water and wind make the problem even worse by removing nutrient-rich soil, gradually leaving nothing but a bare desert behind.

No continent is immune from desertification. Around a third of our planet is directly affected and population pressure is typically the root cause of it.

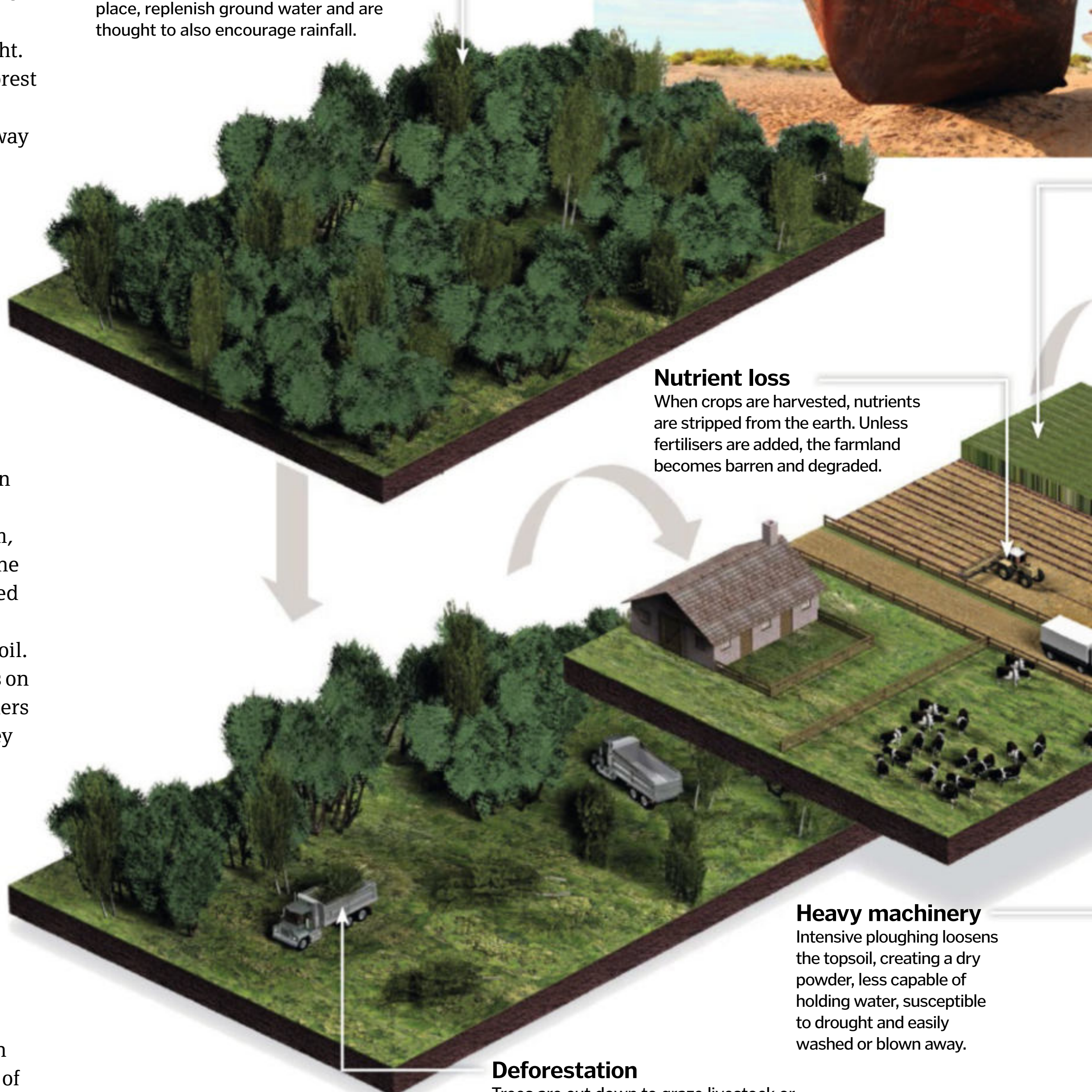
Land degradation is not a new problem, though. Studies suggest the collapse of the Mayan civilisation in 900 CE was triggered by population growth followed by crop cultivation on steep slopes with fragile soil.

Desertification has devastating effects on people and the environment alike. Farmers face famine or the threat of disease if they migrate away from depleted farmland. Dust from the affected land can also cause lung diseases. In China, sandstorms and dunes from the advancing Gobi Desert swallow up entire villages and affect air quality in Beijing some 80 kilometres (50 miles) away.

In Africa's Sahel, desertification increases drought risk too; vegetation dying back exposes the pale sand, which reflects more heat, reducing updraughts of damp air that generate clouds and rain, so once it begins, desertification is self-propagating.

Farmland to wasteland

See how intensive agriculture can transform a fertile landscape into a barren terrain



Easter Island

1 The ancient Rapa Nui who built approximately 900 giant hollow-eyed Moai statues – some weighing 75 tons – may have collapsed after stripping the island of palm forest.

Greenland

2 Cutting down trees for fuel and livestock overgrazing may have contributed to the disappearance of Vikings from Greenland – a cold desert – in the mid-15th century.

Carthage

3 The Ancient Romans are said to have polluted the croplands around Carthage in modern Tunisia with salt after winning the Third Punic War, hoping to render the city uninhabitable.

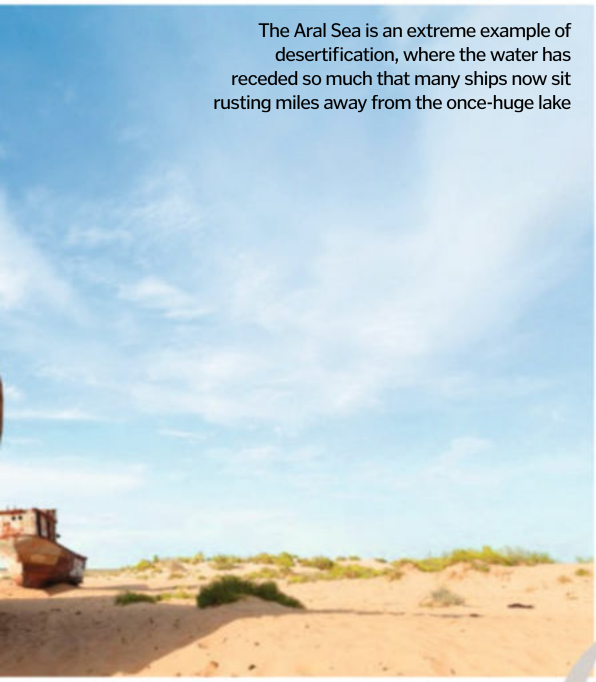
Mesopotamia

4 By the second millennium BCE, farmers in southern Mesopotamia had swapped wheat for salt-tolerant barley, forced by desertification caused by irrigation.

Sardis

5 Sardis, an ancient city in western Turkey, was destroyed by landslides, soil loss and overgrazing. Forests were stripped from the slopes for construction and firewood for Roman baths.

DID YOU KNOW? *A single millimetre (0.04in) of soil can take hundreds of years to form in dry climates*



The Aral Sea is an extreme example of desertification, where the water has receded so much that many ships now sit rusting miles away from the once-huge lake

Desert expansion around the globe

What places on Earth have been most affected by desertification?

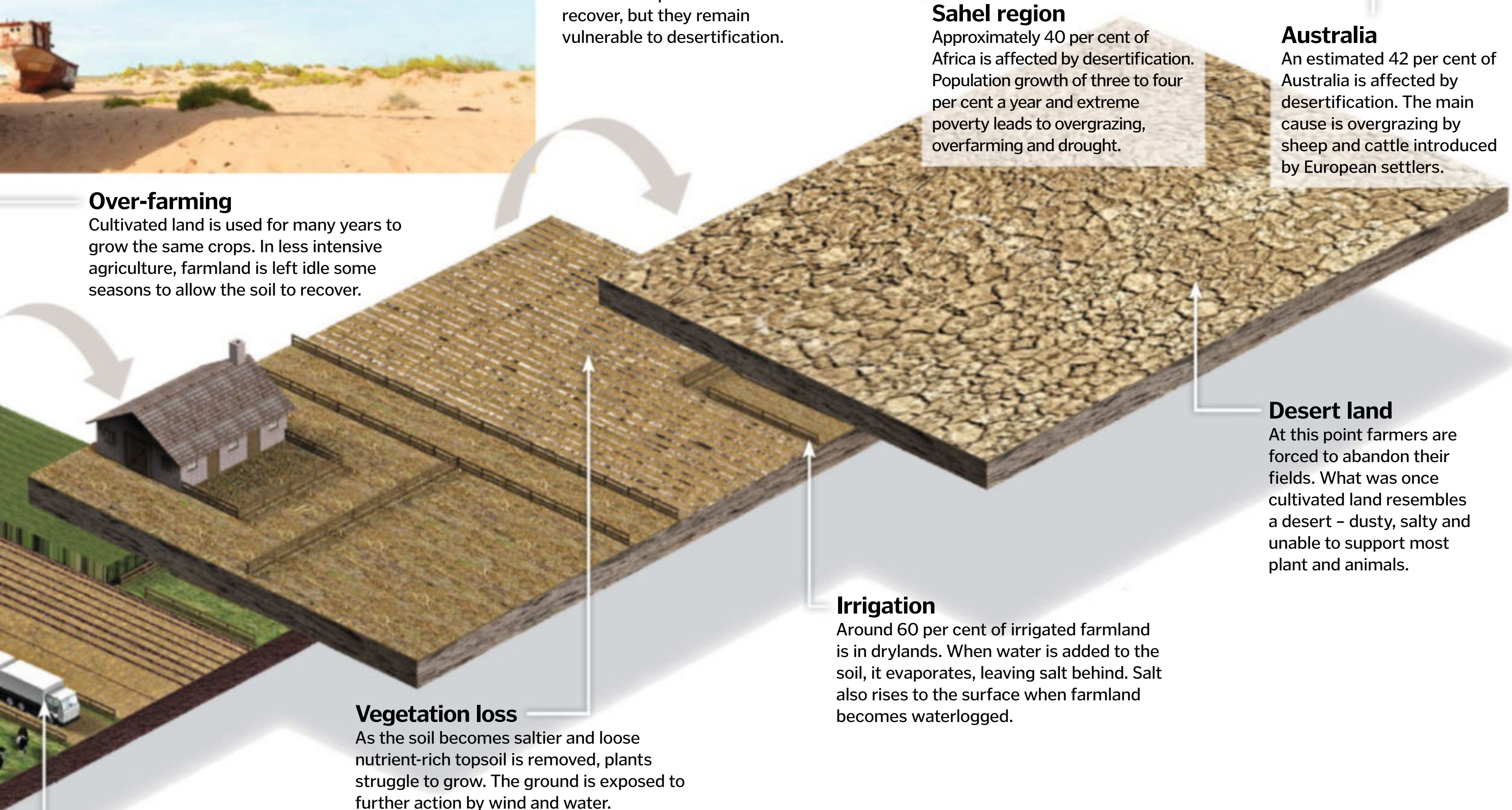
Aral Sea
This giant lake began shrinking in the Sixties when water was diverted to grow cotton. Today it holds ten per cent of its original volume.

Gobi Desert
Around 3,600km^2 (1,400mi^2) of China becomes desert each year, due to the expansion of the Gobi. Causes include overcultivation and population pressure on water and soil.

Great Plains
The US Great Plains turned into a 'dust bowl' when wheat production expanded after WWI. Improved farming methods helped the Plains recover, but they remain vulnerable to desertification.

Sahel region
Approximately 40 per cent of Africa is affected by desertification. Population growth of three to four per cent a year and extreme poverty leads to overgrazing, overfarming and drought.

Australia
An estimated 42 per cent of Australia is affected by desertification. The main cause is overgrazing by sheep and cattle introduced by European settlers.

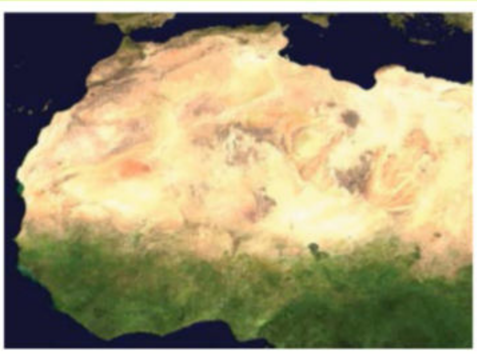


Over-farming
Cultivated land is used for many years to grow the same crops. In less intensive agriculture, farmland is left idle some seasons to allow the soil to recover.

Desert land
At this point farmers are forced to abandon their fields. What was once cultivated land resembles a desert – dusty, salty and unable to support most plant and animals.

Irrigation
Around 60 per cent of irrigated farmland is in drylands. When water is added to the soil, it evaporates, leaving salt behind. Salt also rises to the surface when farmland becomes waterlogged.

Vegetation loss
As the soil becomes saltier and loose nutrient-rich topsoil is removed, plants struggle to grow. The ground is exposed to further action by wind and water.



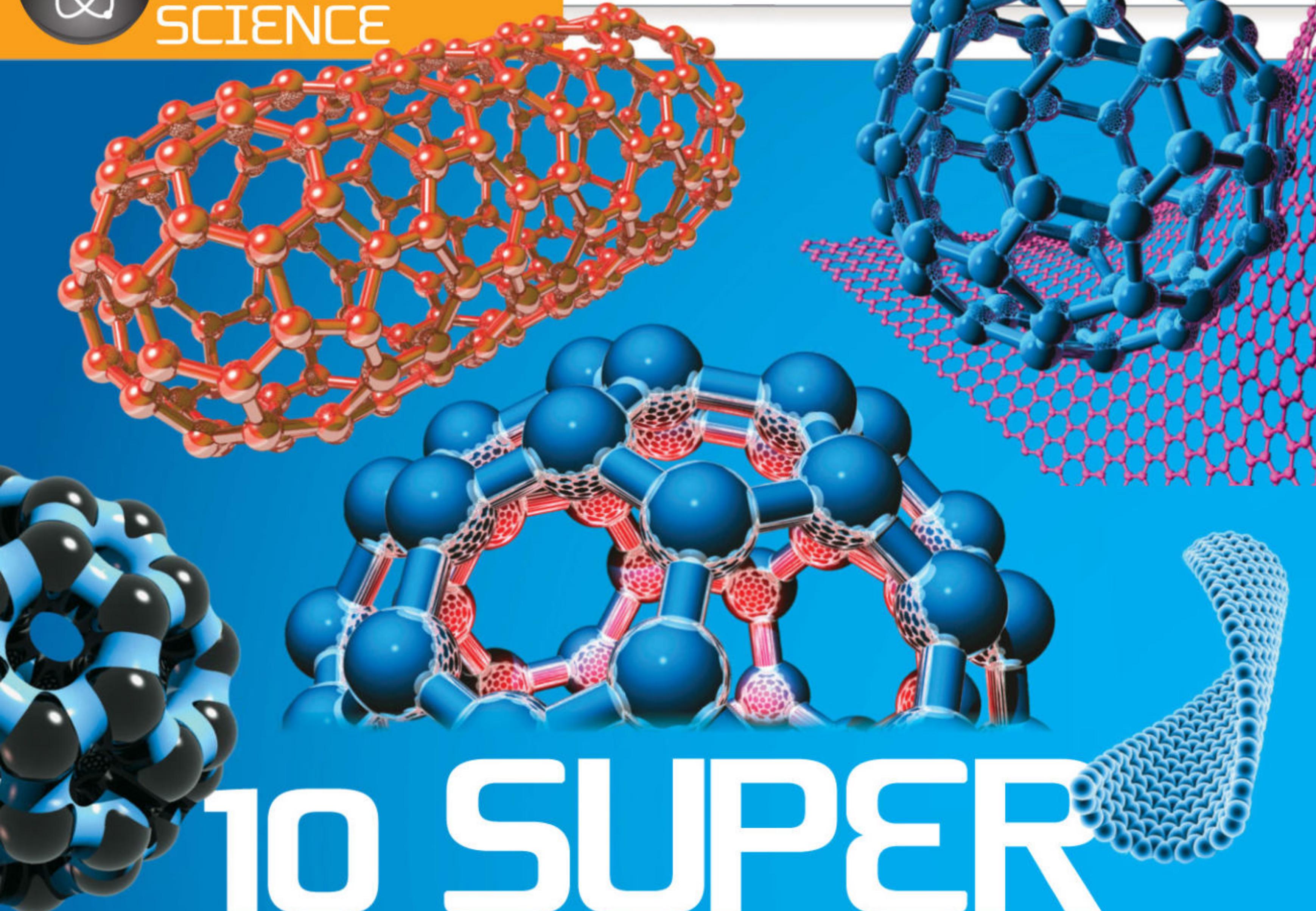
How can we fight desertification?

Reversing desertification depends on tackling human exploitation of land by providing sources of income. Imagine a wall of trees and shrubs – 8,000 kilometres (5,000 miles) long and 15 kilometres (nine miles) wide – snaking west to east across Africa. The Great Green Wall project began in 2011 to counter desertification on the Sahara Desert fringe. Since then, 12 million drought-resistant acacia trees have been planted in Senegal alone.

Large-scale planting schemes were used to tackle desertification in 1935 during the US Dust Bowl too. China initiated its own green-wall project in 1978, which afforested 9 million hectares (22.2 million acres) in the first ten years.

Large forested areas replenish the water table, act as wind breaks to stop sand dunes in their tracks, and may increase rainfall; for example, an estimated 60 per cent of Amazon rainfall is created by the rainforest itself. Advocates of the African green wall believe it can even counter terrorism, providing jobs by producing gum arabic from acacia.

Other techniques to fight desertification include improving irrigation techniques, applying bacteria to dunes and introducing sand fences and pools.



10 SUPER MATERIALS

How are we enhancing Mother Nature's design to develop the new-and-improved materials tomorrow's world will be made of?

With natural resources dwindling and some no longer meeting our needs, a new range of 'super materials' are now being developed in labs around the world. Designed to increase efficiency, these substances are new compounds that build upon and improve what's currently available, to be the best in a particular field.

Natural materials have been used for decades and even centuries to perform many day-to-day tasks, from conducting electricity to insulating heat, but super materials take things to a whole new level. The emphasis is now geared towards the best and only the best. Nothing less than total conduction, extreme strength or complete insulation will do. Essentially these materials will do the job better than anything that has gone before.

Whether it's based on an existing natural substance or an improvement on previous man-made efforts, super materials look to become increasingly important in a world searching for sustainable and greener energy sources. However, many questions still remain. Can we harness these materials and mass-produce them? Will they be available to the general public? Are they as good as they seem?

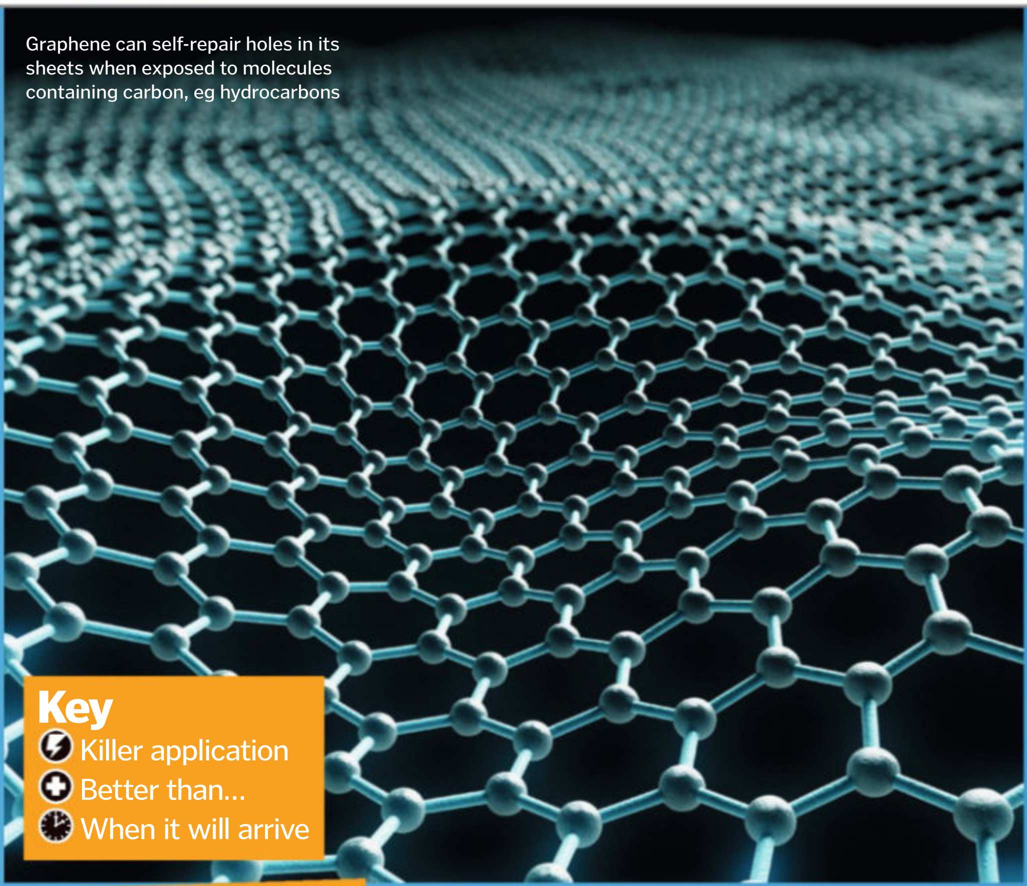
Over the following pages we present our pick of ten of the most impressive super materials that look set to reshape our future.

What makes spider silk so difficult to mass-produce?

A The silk breaks easily B The spiders eat each other C Most spiders are stuck in a bathtub

Answer:
Unlike silk worms, spiders are cannibals so will eat their own if put together to produce silk. They can't be effectively farmed, as it takes hundreds of them to make even small amounts of cloth.

DID YOU KNOW? Diving beetles have hydrophobic hairs that enable them to trap a layer of air under their wings

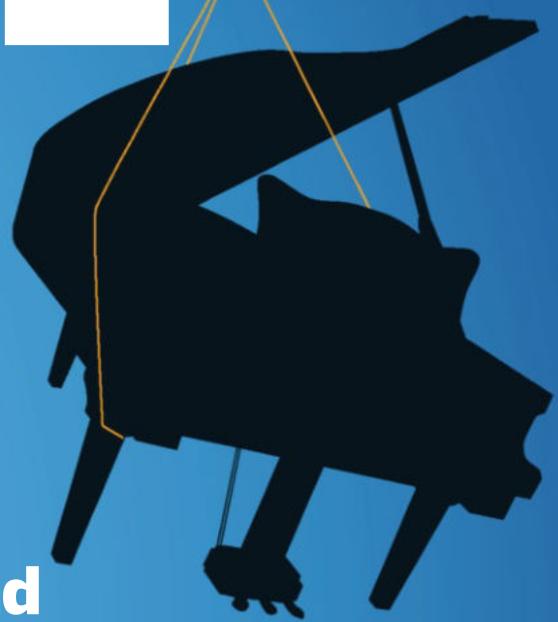


Graphene can self-repair holes in its sheets when exposed to molecules containing carbon, eg hydrocarbons

Key
- Killer application
- Better than...
- When it will arrive

1 grand piano

A strand of graphene as fine as a pencil point can hold up a 450kg (1,000lb) piano



GRAPHENE Stronger than diamond

If super materials had a poster boy, graphene would be it. Composed of a single layer of graphite carbon atoms in a honeycomb pattern, its structure is stronger than diamond. It was first theorised as far back as the mid-20th century but only gained recognition for its astonishing properties when Andre Geim and Konstantin Novoselov experimented with it and went on to claim a Nobel Prize in 2010.

Graphene is famed for its excellent conduction of both heat and electricity. Atomic force microscopy has proved it is, at the very least, 100 times stronger than steel and can be stretched by up to 20 per cent of its own size. It has been used for all manner of things, such as a coating material to nullify lightning strikes, increasing energy storage in batteries and making touchscreens more responsive.

Its coating properties in particular help stop corrosion and prevent micro-organisms from spreading. The electrons within it travel at a hundredth the speed of light as if they carry no mass. Graphene's tiny size makes it ideal for small electronic devices, as its high thermal conductivity enable them to dissipate heat while still maintaining power.

Graphene is also actually the source of many other super materials and is the parent form of carbon nanotubes and buckyballs. However, it was only experimentally isolated on its own accord in the 2000s by the aforementioned Nobel Prize winners.

There are currently only a few ways of producing graphene: mechanical or thermal exfoliation, chemical vapour deposition and epitaxial growth. None of these methods are exactly geared for production on a large scale, so a new way of creating the super material has been proposed. This involves oxidising the graphene that turns it into graphene oxide, which is easier to contain and transport. However, this method is still in its early stages.

Adding this simple carbon allotrope to a variety of surfaces and devices is surely the future as the human race looks to establish ever-more efficient materials. Some are sceptical of the potential of this substance and it's admittedly hard to believe that one material can have so many impressive properties, but graphene undoubtedly still has much to offer.

- Counteracting lightning strikes
- Copper wires at conducting electricity
- Already around, with its uses increasing

Five ways we can use graphene

1. Lightning catcher
Outstanding electrical conductivity means it can not only nullify lightning, but perhaps even harness it. This has never been done, but graphene could be the material for the job.

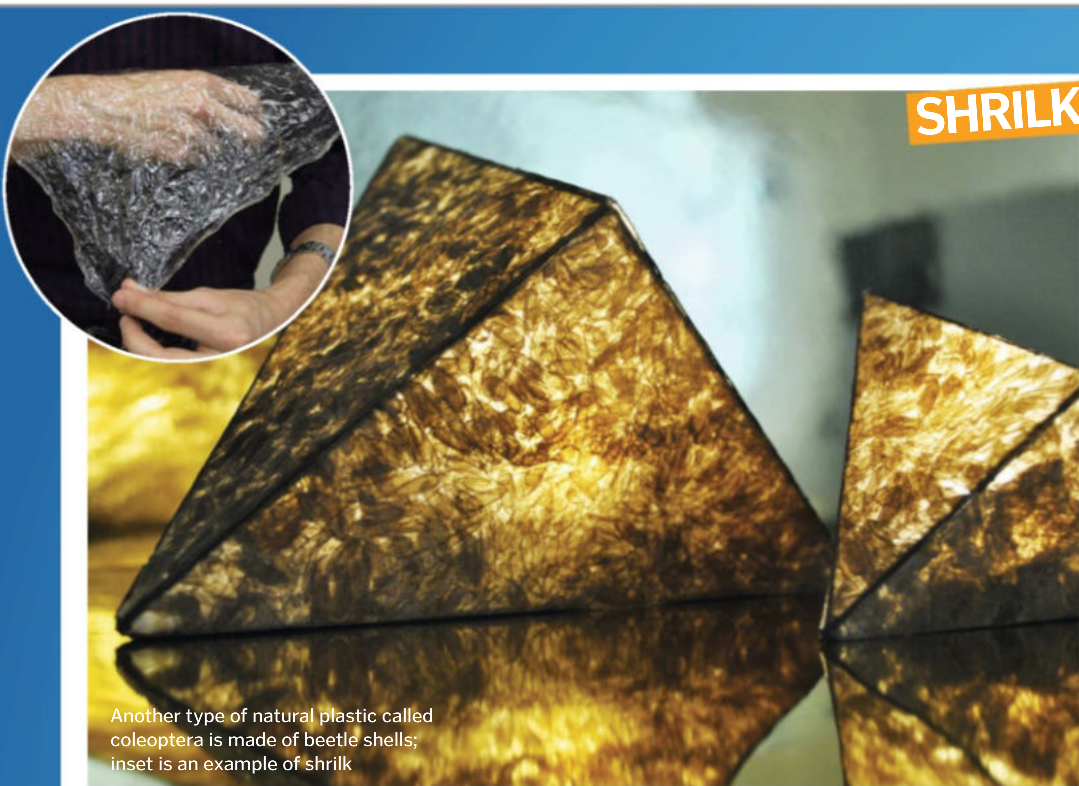
2. Wires
Copper wires are found in all electrical circuits, but graphene can transport 1,000 times the density of copper. Increasing electrical efficiency would cut emissions and fuel use.

3. Coatings
Graphene is useful at creating composite materials and can coat plastics or metals to improve their properties, such as electrical conduction or strength.

4. Touchscreens
Handy for touchscreens on smartphones and tablets, graphene is transparent and can transmit 97.7 per cent of light. Its strength also sees off scratches while keeping flexibility.

5. Bio-engineering
Experts suggest the material could have the capability to monitor glucose and cholesterol levels, as well as aid tissue rejuvenation and even cancer treatments.

"Stanene is said to be able to conduct electricity with 100 per cent efficiency at room temperature"



Another type of natural plastic called coleoptera is made of beetle shells; inset is an example of shrilk

SHRILK
The next generation of plastics

Composed of silk proteins and shrimp shell, shrilk combines biodegradability with excellent flexibility and strength. Based on similar substances in the animal kingdom, shrilk's roots lie in the material found in shells and insect wings. The hope is that the material can replace plastic, which would lessen the impact and size of landfill sites. Like plastic, it's inexpensive and can be used to make clothing, bags and many other everyday products.

In addition to shrilk, there has also been progress with another plastic formed from dead beetle shells – known as coleoptera. This contains chitin, a natural polymer that boasts the light weight and flexibility of conventional plastics but breaks down far more easily.

Shrilk and other biodegradable plastics are great examples of where the fields of biology and engineering create the ultimate material solutions.

- Potential to replace plastic
- Lighter than aluminium and equally strong
- More research needed to be mass-produced

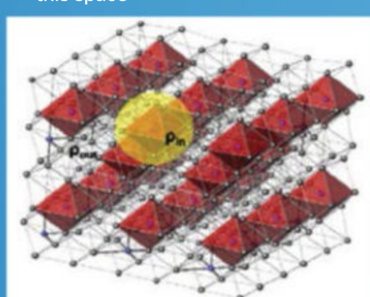
Strongest magnet in the world
IRON NITRIDE

The most magnetic material on Earth is a mix of iron and nitrogen with the chemical symbol $Fe_{16}N_2$. It's claimed that the material has the strongest saturation magnetic flux density of any man-made substance. This means that the strength of magnetism is the most per unit of molecule within the iron nitride, making it hugely magnetic over its entire surface. Powered by ferromagnetism, iron nitride is electrically uncharged but that doesn't affect its power.

Every electron within the material acts like a tiny magnet. The Fe-N clusters increase electron contact, which intensifies the charge. It's so magnetic that it exceeds the predicted limit of magnetism for a single material. Iron nitride has taken over from the previous holders, neodymium and iron cobalt, to claim the plaudits for the most magnetic material on Earth. It's at least twice as magnetic as its rivals (rated at 130 megagauss oersteds).

Magnets of this magnitude are used in industry and engineering to increase the efficiency of power-production. They are often used as electromagnets within transformers, for example.

- Making disk drives more effective
- Neodymium and iron cobalt
- Still in the testing stages – watch this space



"High magnetic fields play a critical role in developing new materials that affect nearly every modern technology. The vast scope of work currently underway includes the study of new superconductors with the potential to revolutionise how power is stored and delivered. There's also a search for new medicines and analysis of petroleum samples that could lead to better oil extraction"

Greg Boebinger, director at the National High Magnetic Field laboratory, Florida State University

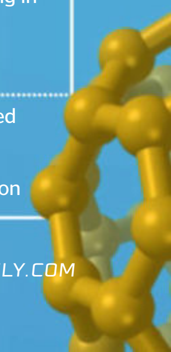
STANENE
The perfect conductor

Composed of a single layer of tin atoms, stanene is said to be able to conduct electricity with 100 per cent efficiency at room temperature.

This astonishing electrical conductivity has seen it dubbed by some as the new graphene and it's expected to play a big role in the future of computer chips.

Stanene is part of a group of topological insulators that conduct electricity only on their outer edges. Being only an atom thick, the electrons can travel through the material with no resistance, which improves efficiency. However, stanene is the first of these topological insulators to work at room temperature. Difficult to produce due to its minuscule size, the material is still in the developmental stages. There's also talk of adding in a layer of fluorine to increase conduction efficiency at higher temperatures as well.

- Boosting the processing speed of computer chips
- Potentially even graphene
- Far from wide-scale production



AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Graphene: journey to the super material king

www.howitworksdaily.com

DID YOU KNOW? *Nanotubes could theoretically be used to make an Earth-to-orbit space elevator*

SUPER-HYDROPHOBIC MATERIALS

The hydrophobic qualities of plants like nasturtiums have been applied to glasses in traffic control units, medical slides and circuit boards (inset)

Completely waterproof

Man-made waterproof materials have paled in comparison with natural examples such as the lotus leaf and insect wings – until now. Known as the most waterproof material ever, super-hydrophobic surfaces have been developed at the Massachusetts Institute of Technology (MIT) and are inspired by butterfly wings and nasturtium leaves.

Often referred to as the lotus effect, nature's waterproof materials defend themselves from water through a special structure. They are covered by bumps or hairs that when exposed to liquid can direct it away from the body. Various man-made materials have taken advantage of this technique, including synthetic silicon, polymer microposts and electro-deposited copper. These coatings, like the organic inspiration, enable water droplets to bounce off a surface to keep it dry. The materials have small ridges that break up the water on the surface and disperse it before it can soak through.

Some of these materials are being pushed even further, with efforts to make them repel ice and snow too. Hydrophobic materials are perfect for everything from clothing to tents and vehicle coatings.

- A de-icer that will rapidly clear snow and ice
- Lotus leaves have finally been surpassed
- Already available in clothing and more

"To be super-hydrophobic, a material requires both hydrophobic chemistry and roughness. The trapped layer of air, under certain situations, may act to reduce the drag on an object passing through water"

Michael Newton, Nottingham Trent University

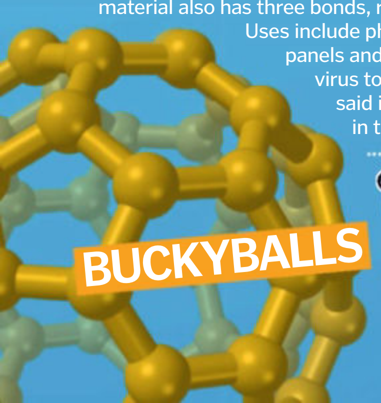
The original super material

Affectionately known as buckyballs, buckminsterfullerene is one of eight carbon allotropes that include diamond, graphene and carbon nanotubes. Discovered by accident, buckminsterfullerene can be considered the daddy of super materials. Its discovery paved the way for the modern era of nanotechnology and proved that materials with extreme properties could be found and worked on. It has led to the discovery of carbon nanotubes as scientists were encouraged to enhance carbon allotropes further in the search for the next carbon nanomaterial.

The allotrope is shaped a bit like a football, with a hexagonal and symmetrical polyhedral structure. A tough skeleton of 60 carbon atoms makes buckminsterfullerene even stronger than diamond under certain conditions. Every carbon atom within this super material also has three bonds, resulting in its incredible strength.

Uses include photovoltaic applications in solar panels and the inhibition of a protein in the HIV virus to stop it replicating. Some have even said it could limit oxidative stress of cells in the body that cause ageing.

- Could combat HIV and cancer
- Diamond when tested for hardness under high pressure
- Widely used since 1985



BUCKYBALLS

"Superglue is a polymer-based adhesive of the cyanoacrylate type that is polymerised upon contact with a surface and moisture. Some of the uses of these adhesives can be in the form of coatings, fillers, forensics, or even for medical uses like closing [open] wounds"

Rigoberto Advincula, professor of macromolecular science and engineering at Case Western Reserve University, OH, USA

MOLECULAR SUPERGLUE

Most adhesive glue

First there was glue, then there was superglue, but now there is molecular superglue. From the cyanoacrylate (instant glue) family of adhesives, it is designed to be the most adhesive material on the planet and will primarily be used to fight disease.

Genetically engineered from proteins, the glue is polymer-based and formed from nanotechnology that bonds molecules together to form tough covalent bonds. The technology enables the protein to react with itself to form a tight lock. Most effective when used thinly, the glue is made from the proteins of the streptococcus pyogenes bacteria, enabling it to hook on to human cells.

Even more impressive, the glue can be designed to be selective to what it sticks to. This is essential, as an adhesive this strong would cause havoc if it got stuck to the wrong objects!

- Closing up wounds in seconds
- Any previous superglue – and a whole other league to PVA glue
- Here now, but its uses are not fully confirmed

"Carbon aerogels are predicted to be used as a new type of faster charging and discharging battery"

AEROGELS

Solids that are lighter than air

7x lighter than air
Aerogels are so light a flower or seed head can support them

Created by removing liquid from a gel, aerogels are the world's lightest solid materials. High in strength and low in density, they are mesoporous, which means they contain lots of tiny pores, contributing to their low density. There are various types of aerogels, all with different functions and abilities.

First, silica aerogels have an extremely low thermal conductivity and can be used as super-insulators. The most common of the gels, these have even been used on expeditions to Mars.

Carbon aerogels can store high amounts of energy and are ideal as fast-charging super-capacitors. They are predicted to be used as a new type of faster charging and discharging battery in mobile phones and electric cars.

Lastly, metal aerogels combine the properties of the two substances. Being highly conductive and having a high surface area, X-ray optics and hydrogen storage are just two of the possible functions for this hybrid material.

- Protection in firefighter suits
- Surpasses all other heat insulation
- Currently used, but development continues

TITANIUM FOAM

The metal that can replace bone

Metal foams are generally solid metals filled with tiny holes, known as 'cells', and up to 95 per cent of their volume can be air. Their biggest selling point is that while they are light and porous, they retain much of their original strength. Made from a mix of metal powder and polyurethane, a binding agent fixes the two substances together under heat.

Titanium foam in particular is tough but at the same time has very similar properties to bone. Experts predict that bone will be able to naturally regrow around it, making this material a very attractive prospect for mending breaks and fractures. Also corrosion-resistant, it can endure nearly all chemicals, making it useful not just as a biocompatible material in the body but also for aerospace components.

- Currently used on drones and lightweight aircraft
- Many metals used in construction
- Expected to be used in bone-reconstruction as soon as research confirms its viability

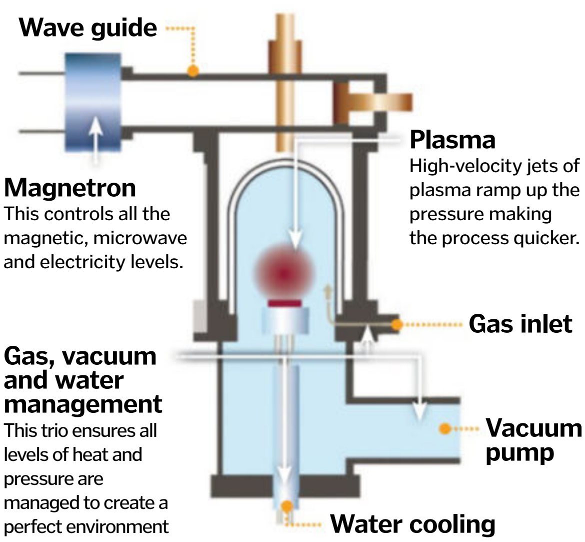
An SEM shows up the thousands of cells inside a metal foam that are reminiscent of our bone structure

"Titanium is light, strong and, most importantly, corrosion-resistant. The most vital application of titanium foam is as artificial bones, because it can be tailored to have similar mechanical properties to human bones and the porous structure is conducive to ingrowth of tissue cells"

Yuyuan Zhao, head of the Centre for Materials and Structures, University of Liverpool

Make your own diamond

Famed for their beauty and toughness in the natural world, diamonds are becoming increasingly rare. Steve Coe, from synthetic diamond manufacturer Element Six, takes us through two ways they're re-creating these gems for drilling, optics, acoustics and more.



Magnetron
This controls all the magnetic, microwave and electricity levels.

Plasma
High-velocity jets of plasma ramp up the pressure making the process quicker.

Gas, vacuum and water management
This trio ensures all levels of heat and pressure are managed to create a perfect environment to form diamonds.

Chemical vapour deposition

Chemical vapour deposition (CVD) uses a hydrocarbon gas mixture, where the diamond is produced in a vacuum system below atmospheric pressure, with carbon atoms supplied from a gas such as methane and deposited in layers onto a substrate.

By passing microwaves through the gas to generate a plasma, at temperatures around 2,000°C (3,632°F), atomic hydrogen is created, enabling impurities in the form of graphite to ensure only the diamond carbon is deposited.

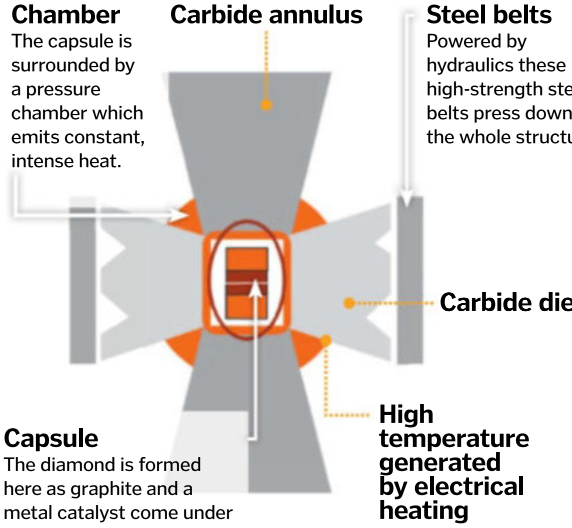
This technique enables tightly controlled growth conditions, eliminating impurities and enabling the engineering of various properties into the diamond material.

High-pressure high-temperature diamond synthesis (HPHT)

This is a synthesis process by which synthetic diamond is created under enormous pressure and temperatures to replicate the Earth's natural process.

The proprietary belt-press technology contains two large anvils to apply hydraulic force to a capsule at the centre.

This capsule contains graphite and a metal catalyst, which react during the process to form diamond. The 15,000 atmospheres of pressure applied to the capsule is the equivalent of taking the Eiffel Tower, inverting it and placing it on a soda can, then turning the temperature up to 1,500°C (2,732°F) – the melting point of steel.



Chamber
The capsule is surrounded by a pressure chamber which emits constant, intense heat.

Steel belts
Powered by hydraulics these high-strength steel belts press down on the whole structure.

Capsule
The diamond is formed here as graphite and a metal catalyst come under intense pressure and heat.

5 TOP FACTS
MATERIAL MARVELS

Plastic
1 First created in the late-19th century, plastics still play an essential role in manufacturing and industry on almost all levels of industry across the globe today.

Safety glass
2 Made in the early-20th century, a thin layer of plastic is added to glass so it doesn't shatter or splinter, making ever-taller buildings much safer than before.

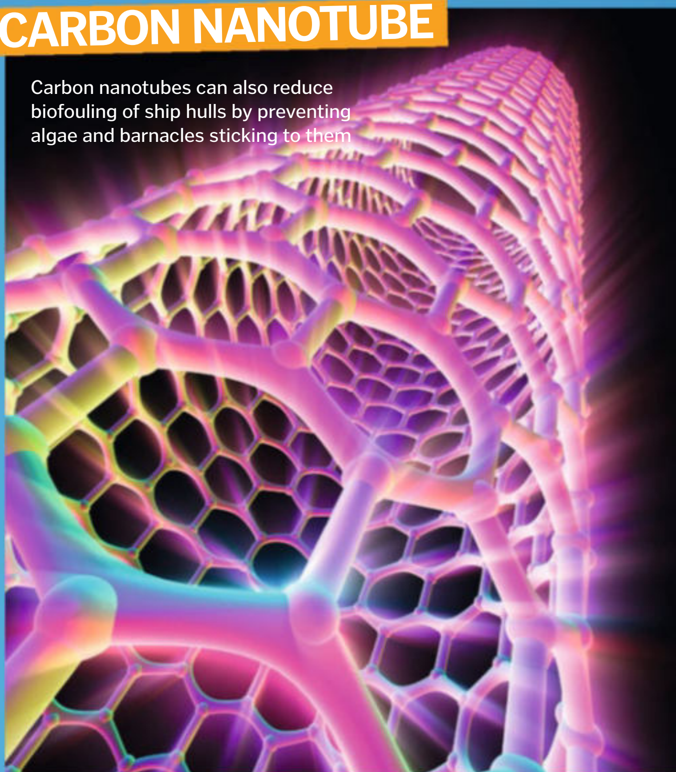
Stainless steel
3 Originally called rustless steel, the new type of steel formed a passive corrosion layer to protect itself from oxides, increasing both its strength and overall longevity.

Fibre optics
4 Able to transmit over great distances, optical fibres enabled the modern age of the internet, broadcasting and even telecommunications to really take off.

Kevlar
5 An artificial fibre developed and produced in a lab, Kevlar is still one of the strongest materials on Earth and is frequently used in body armour by police and soldiers.

DID YOU KNOW? *The most powerful man-made magnets have fields more than a million times stronger than Earth's!*

CARBON NANOTUBE



Carbon nanotubes can also reduce biofouling of ship hulls by preventing algae and barnacles sticking to them

Absorbs over 99.5% of light

Carbon nanotubes are said to outperform Kevlar and steel in strength. By having a high specific strength, carbon nanotubes can absorb high impacts by spreading out the force. As well as being strong, the fibre is also ductile and malleable. These characteristics render the material useful as a possible replacement for steel, as well as being applied as synthetic muscles and body or vehicle armour.

If all that wasn't enough, the computing world has also found a use for this super material with its potential to be a long-term replacement for today's silicon computer chips.

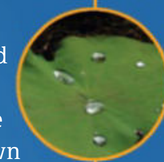
Moreover, certain types of carbon nanotube developed by NASA are said to be the darkest material known to man, due to their ability to absorb over 99.5 per cent of photons. This is particularly useful for stopping stray light interfering with sensitive equipment on probes and spacecraft. This property also offers huge potential for more effective solar panels.

- Absorbing multiple wavelengths of light
- Silicon transistors in electronic devices
- Environmental concerns have stalled its progress so far

800°C
A nanometre of carbon nanotubes is heat resistant enough to withstand lava

"Carbon nanotubes are molecular-scale tubes of graphitic carbon with outstanding properties. They are among the stiffest and strongest fibres known, with a breaking strain around 50 times higher than steel. Carbon nanotubes have an important advantage over graphene, in that they are stiff and strong in compression as well as tension; graphene can't withstand any compression"
Peter Harris, Reading University, and author of *Carbon Nanotube Science*

5 natural inspirations



1 Lotus leaf
When raindrops land on the leaves of the lotus, they cannot settle on the plant. This is down to microscopic bumps over the surface, which increase the contact angle. As the water hits these protrusions, with pockets of air trapped in between, it beads up into spheres and rolls off.

2 Gecko feet
Geckos have the ability to cling to surfaces with adhesive pads called setae on their feet. However, this skill comes undone in wet weather, hence why scientists today are looking to advance on this natural ability by making a waterproof adhesive.

3 Kawazulite
This mineral is a conductor on the outside and an insulator on the inside. It looks set to play a big role in future synthetic insulators.

4 Spider silk
Tough and adaptable, spider silk has been used for everything from fish nets to gun crosshairs. Humans have created similar synthetic products such as Kevlar, however these generate a great deal of pollution.

5 Gold nanoparticles
Also called nanogold, these tiny particles are 500 times smaller than the width of a human hair. They have excellent molecular-recognition properties and can detect the proteins on cancer cells by using specialised antibodies.

"a rainforest for your desk"
T3 magazine

☆☆☆☆☆

"a miniature Jurassic Park"
ShortList magazine

☆☆☆☆☆

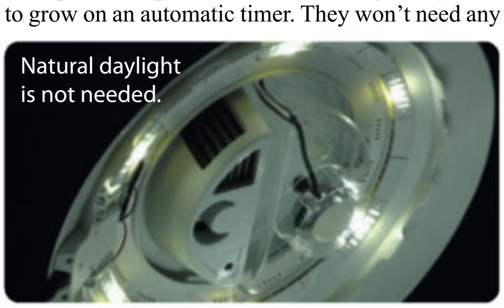
"a miniature Eden Project for a touch of the great outdoors"
Daily Express

"Enjoy the beauty of a rainforest in your home"

biOrbAIR is an automated terrarium that offers hassle-free plant care. You can fill it with hard-to-maintain exotic plants and the sealed environment takes care of the rest: lighting, humidity, watering and air circulation.

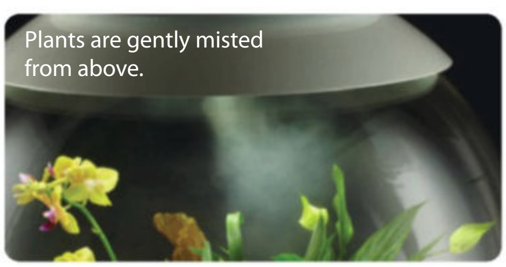
It needs no daylight.

Your plants are provided with all the light they need to grow on an automatic timer. They won't need any extra daylight, so you can place the biOrbAIR anywhere in your home.



Humidity is automatically controlled.

The biOrbAIR senses when the humidity drops and gently mists your plants when needed to keep them perfectly hydrated.



Easy to set up and own.

The biOrbAIR is simple to set up and is virtually maintenance free. Once established, your plants will flourish. When the water reservoir gets low, your biOrbAIR will remind you to top it up by gently dimming it's lights.

100% guaranteed.

All the working parts in your biOrbAIR are backed by our 12 month guarantee.

GUARANTEE 12 MONTH GUARANTEE

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5 TOP FACTS
TEARY TRIVIA

Runny noses
1 If you find that your nose runs a lot when you cry, it is because excess tears are running from your eyes, down your tear ducts and into your nose, causing those tearful sniffles.

Hush, little baby
2 Babies typically cry for about one to three hours per day. This can be for a variety of reasons, because they're hungry, thirsty, tired, scared or have just been to the toilet.

Onion weeping
3 Syn-propanethial-S-oxide is created by an enzyme in a cut onion. When it evaporates, this compound irritates our lacrimal glands and tears are triggered in order to dilute it.

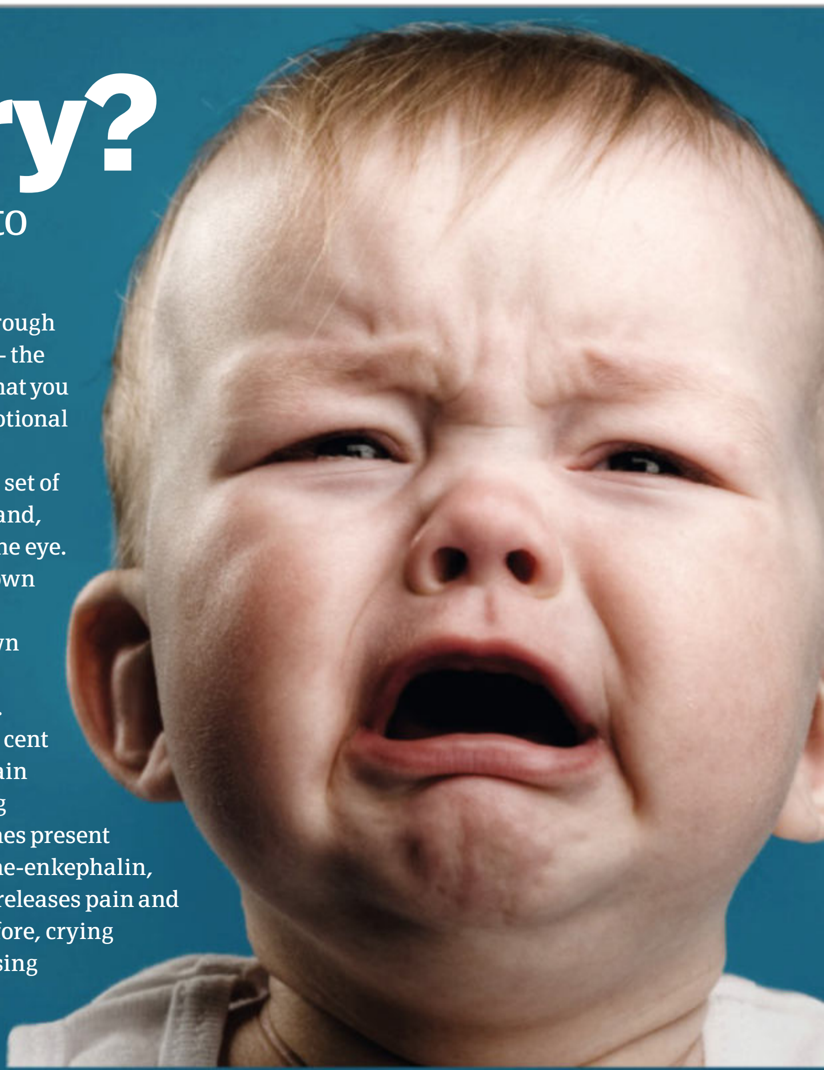
Crocodile tears
4 While crocodiles are known for looking teary as they eat food they've just caught, they aren't sad. The tears merely lubricate their eyes when they spend time out of the water.

Darwin's discovery
5 There is a condition called the PseudoBulbar Affect (PBA) in which people cry or laugh uncontrollably. First described by Charles Darwin it is often the result of brain injuries.

DID YOU KNOW? The average person will produce 140-280g (5-10oz) of basal tears per day to keep the eyes moist

Why do we cry?

Find out how our tears have been helping to protect us since the dawn of time



Whether it's a sad film, a joyous reunion or simply that you've just banged your knee on the coffee table, everyone has cried at some point in their life. But why have we evolved to do it?

There's a theory that it stems right back as far as our pre-evolved days, where tears streaming down our primitive eyes and blurring our vision was a sign of surrender, proving that we meant our aggressor no harm.

But moving on to the present day, the science shows that there are a number of sound biological reasons for tearing up.

There are reflex tears, the stream caused by getting smoke or sulphenic acid from a chopped onion into your eye. When this happens, sensory nerves in your cornea send a signal to the brain that the eyes need protecting. The brain then releases hormones into the lacrimal glands located behind the eyelid, which produces tears to provide a layer of protection and to water down the irritant.

However, the more common form of crying is the emotional kind. When strong emotions are brought about – whether through happiness, sadness or pain – the brain's cerebrum is aware that you are undergoing a strong emotional reaction to a stimulus. The endocrine system releases a set of hormones to the lacrimal gland, which secretes liquid onto the eye. Excess water can escapes down the nose, via the tear ducts.

Studies of tears have shown that there is a biochemical reason for emotional crying. While reflex tears are 98 per cent water, emotional tears contain several chemicals, including adrenocorticotropic hormones present in times of stress, and leucine-enkephalin, which is an endorphin that releases pain and improves your mood. Therefore, crying appears to be a way of releasing hormones and toxins that build up during times of intense emotion.

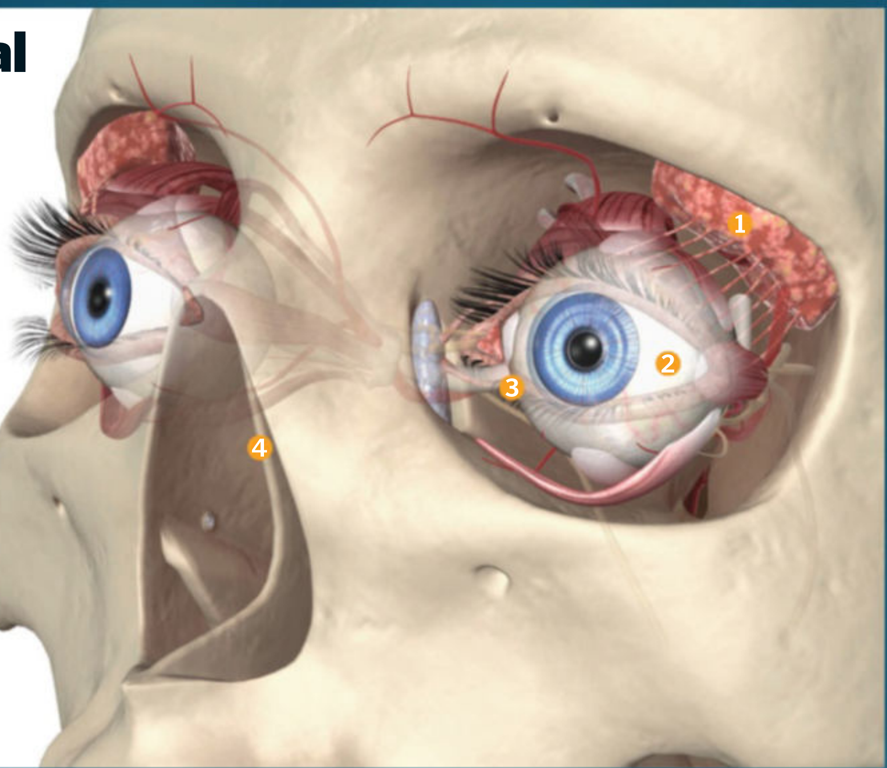
The lacrimal system

1 Lacrimal gland
This gland receives the message from the cerebrum to produce tears.

2 Cornea
Tears help protect the surface of the eye.

3 Tear ducts
This is where the water flows to. If there's too much, it flows down the face.

4 Runny nose
Tears that flow through the tear ducts go down a nasal passage, which is what causes a runny nose.



Battle of the sexes

While there is a stereotype that women are tearier than men, there is some science to explain the reasons behind this. Studies have shown that women cry about four times as often as men and, while there are cultural factors to be taken into consideration, there are biological factors too.

Until their adolescent years, boys and girls cry fairly equally. As testosterone levels rise in boys, they are more likely to get angry than upset. Meanwhile, girls gain increased oestrogen levels, which modifies endorphin production, often leading to more emotional responses to stimuli.

But approaching middle age, men's testosterone and women's oestrogen balance out, once again putting both genders on a more even footing when it comes to crying.

"Being so important, the nucleus is the most-protected part of the cell"

Inside a nucleus

Dissecting the control centre of a cell

Surrounded by cytoplasm, the nucleus contains a cell's DNA and controls all of its functions and processes such as movement and reproduction.

There are two main types of cell: eukaryotic and prokaryotic. Eukaryotic cells contain a nucleus while prokaryotic do not. Some eukaryotic cells have more than one nucleus – called multinucleate cells – occurring when fusion or division creates two or more nuclei within the cytoplasm.

At the heart of a nucleus you'll find the nucleolus; this particular area is essential in the formation of ribosomes. Ribosomes are responsible for making proteins out of amino acids which take care of growth and repair.

Being so important, the nucleus is the most-protected part of the cell. In animal cells it is always located near its centre and away from the membrane to ensure it has the maximum cushioning. As well as the jelly-like cytoplasm around it, the nucleus itself is filled with nucleoplasm, a viscous liquid which maintains its structural integrity.

Conversely, in plant cells, the nucleus is more sporadically placed. This is due to the larger vacuole in a plant cell and the added protection that is granted by a cell wall.

Central command

Take a peek at what's happening inside the 'brain' of a eukaryotic cell

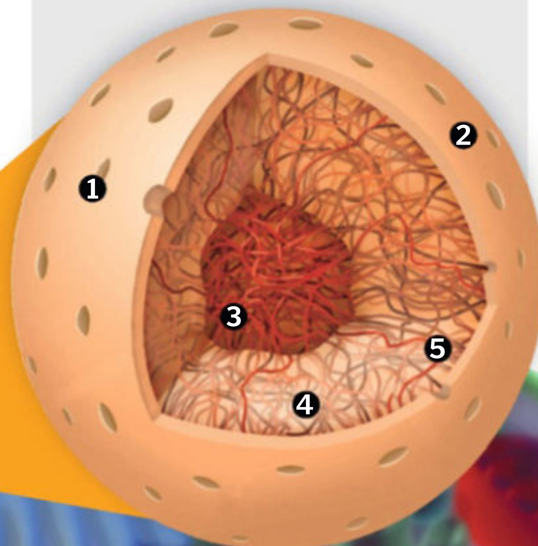
1 Nuclear pore
These channels control the movement of molecules between the nucleus and cytoplasm.

2 Nuclear envelope
Acts as a wall to protect the DNA within the nucleus and regulates cytoplasm access.

3 Nucleolus
Made up of protein and RNA, this is the heart of the nucleus which manufactures ribosomes.

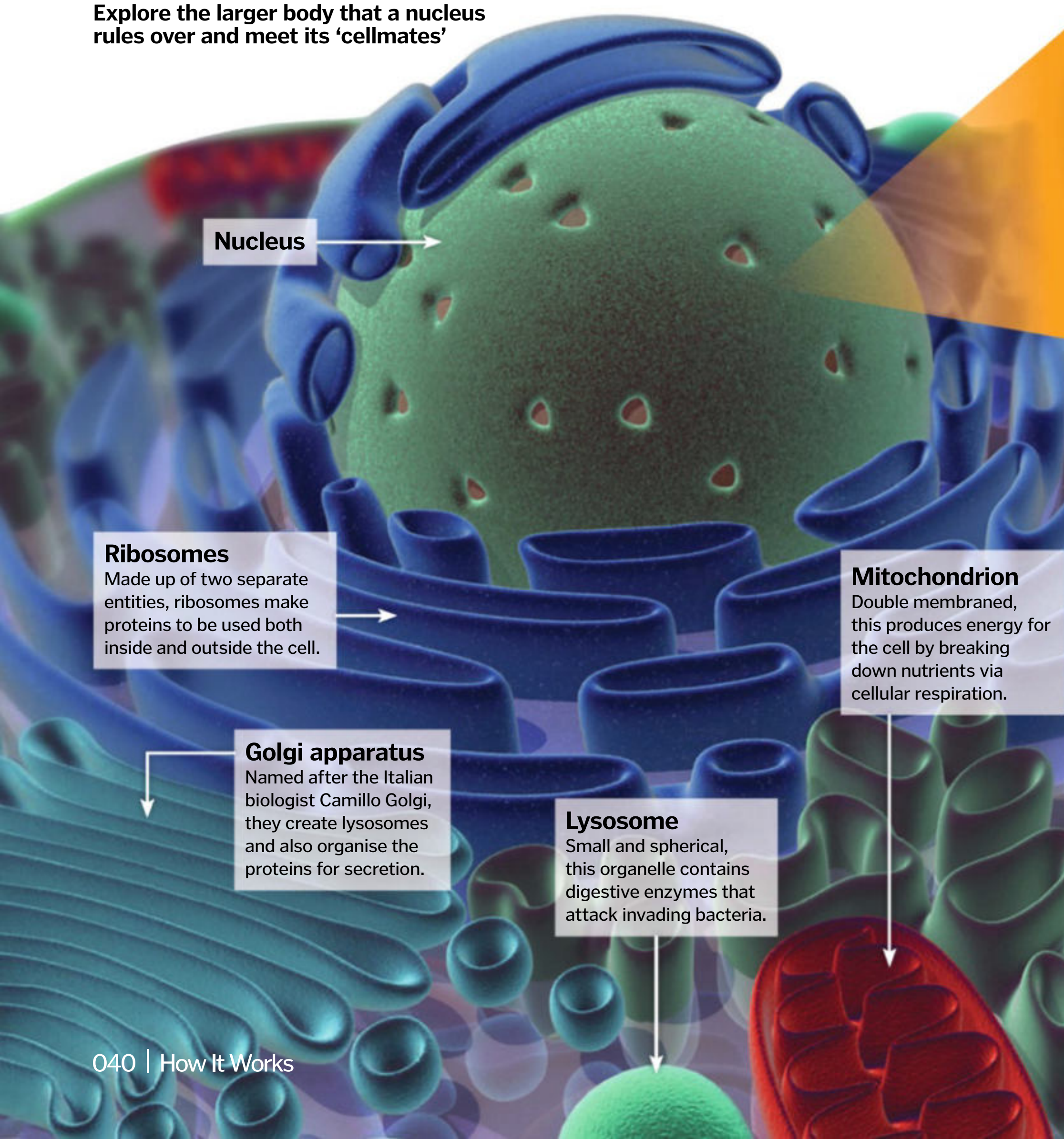
4 Nucleoplasm
This semi-liquid, semi-jelly material surrounds the nucleolus and keeps the organelle's structure.

5 Chromatin
Produces chromosomes and aids cell division by condensing DNA molecules.



Nucleus in context

Explore the larger body that a nucleus rules over and meet its 'cellmates'



Ribosomes
Made up of two separate entities, ribosomes make proteins to be used both inside and outside the cell.

Mitochondrion
Double membraned, this produces energy for the cell by breaking down nutrients via cellular respiration.

Golgi apparatus
Named after the Italian biologist Camillo Golgi, they create lysosomes and also organise the proteins for secretion.

Lysosome
Small and spherical, this organelle contains digestive enzymes that attack invading bacteria.

How do cells survive without a nucleus?

Prokaryotic cells are much more basic than their eukaryotic counterparts. Up to 100 times smaller and mainly comprising species of bacteria, prokaryotic cells have fewer functions than other cells, so they do not require a nucleus to act as the control centre for the organism.

Instead, these cells have their DNA moving around the cell rather than being housed in a nucleus. They have no chloroplasts, no membrane-bound organelles and they don't undertake cell division in the form of mitosis or meiosis like eukaryotic cells do.

Prokaryotic cells divide asexually with DNA molecules replicating themselves in a process known as binary fission.

KEY DATES
SILVER LINING

1000 BCE Silver is first used by civilisations such as Ancient Egypt and Persia to preserve food and water.

69 BCE Hippocrates uses the element in Ancient Greece to help treat wounds.

980 CE Silver is used by experts of the Islamic Golden Age, such as Avicenna, as a blood purifier.

1520 Paracelsus frequently uses silver nitrate to treat wounds during the Renaissance period.

1914-1945 Silver is used throughout the World Wars until the discovery of penicillin begins to limit its use.

DID YOU KNOW? Foucault was only an amateur scientist when he first created his pendulum

How do silver plasters heal?

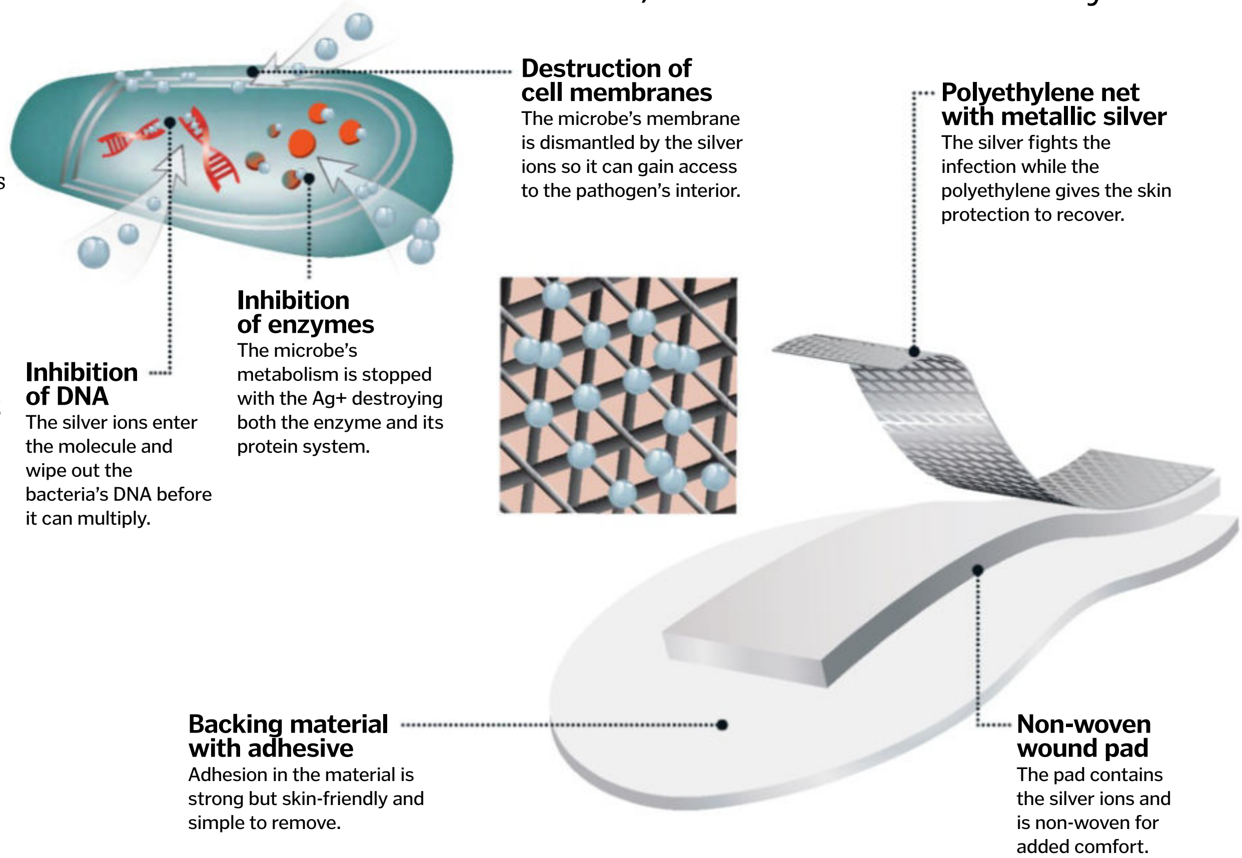
The precious metal has been used in medicine for centuries, but is it still effective today?

Used as early as Ancient Egyptian times, silver has played a role in medical care throughout history.

Before the discovery of antibiotics in the early-20th century, silver helped fight infection. It contains natural antibiotics and is not toxic to humans, which explains its widespread use in jewellery.

Silver works by penetrating a microbe's membrane and disabling the enzymes needed to metabolise nutrients. By eliminating these pathogenic micro-organisms, the silver ions halt the spread of an infection to other healthy cells.

The British NHS reportedly spends over £20 million ($33 million) on silver for use in its hospitals. It has seen a resurgence recently after it was predicted that it could help mitigate the rise of 'superbugs', which are growing ever-more resistant to conventional broad-spectrum antibiotics.



Foucault pendulums explained

How the rotation of the Earth was first proven in a Parisian cellar…

The way the Earth rotates was an issue of constant debate by physicists. This was until the creation of the Foucault pendulum by Jean Bernard Leon Foucault.

In January 1851 Foucault constructed the first of his pendulums in his cellar. Using a simple wire and a heavy weight known as a 'bob' on the bottom, Foucault successfully demonstrated how the Earth spins.

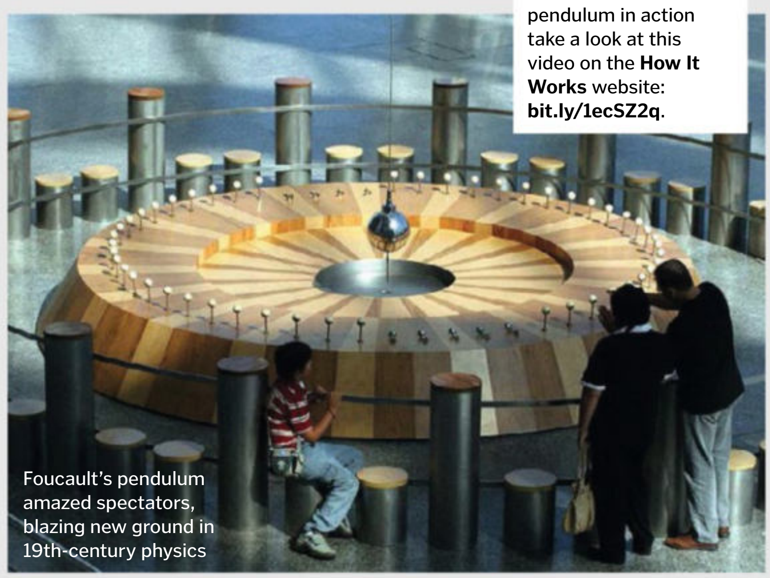
The pendulum began by swinging normally backward and forward but, as time progressed, it began to rotate clockwise at a rate of about 11 degrees an hour, without any apparent interference. This showed how our planet is moving, as there were no other forces acting upon it so our planet's rotation must have been changing its inertia. In other words, Earth is moving, not the pendulum.

The amount of rotation exhibited depends on where in the world the pendulum is: at the poles it covers a full 360 degrees each day, but at the equator it does not twist since it moves along Earth's rotational axis.

Foucault went on to popularise the gyroscope as an instrument to further represent planetary spin but this discovery was arguably his greatest breakthrough.

Learn more

To see a Foucault pendulum in action take a look at this video on the **How It Works** website: **bit.ly/1ecSZ2q**.



Foucault's pendulum amazed spectators, blazing new ground in 19th-century physics

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DID YOU KNOW? *Brazilian Didi was the first top-level footballer to master the curling free kick, called the dry leaf technique*

The physics of football

Discover the science that lies behind taking the perfect free kick

The likes of David Beckham and Cristiano Ronaldo are known around the world for their expertise in the art of the free kick. Whether it's a curler into the top corner or a thundering piledriver, free kick taking is a vital part of the modern game. But how does science come into scoring a goal?

The guiding principle is the Magnus effect. Investigated by German physicist Heinrich Gustav Magnus, this law of physics demonstrates that airflow is distorted around any spinning cylinder or sphere in a certain way.

If the ball is spinning anticlockwise, the left side of it will experience less drag as it moves in the same direction as the airflow, while the right side spins against the onrushing air, increasing the drag. This creates a pressure imbalance, with the right side of the ball experiencing higher pressure and the left side experiencing lower pressure. It is this imbalance which forces the ball to move to the area with lower pressure, thus curling to the left.

But the Cristiano Ronaldo or Gareth Bale style of free kicks is a whole different ball game. The idea behind the immensely powerful, swerving free kick is imparting as little spin as possible. As the air flows over the ball, a boundary layer is produced, which is a cushion of air that sticks very tightly to the surface of the ball. If an imperfection in the ball disrupts this airflow, it will deviate in the air.

A rapidly spinning football won't deviate much, but a ball hit flatly will, as it will have more time to move in the direction of the disruption. So when Ronaldo strikes the ball with little spin, any minor imperfection in the football will cause it to move during flight and outfox many a poor, bewildered goalkeeper.

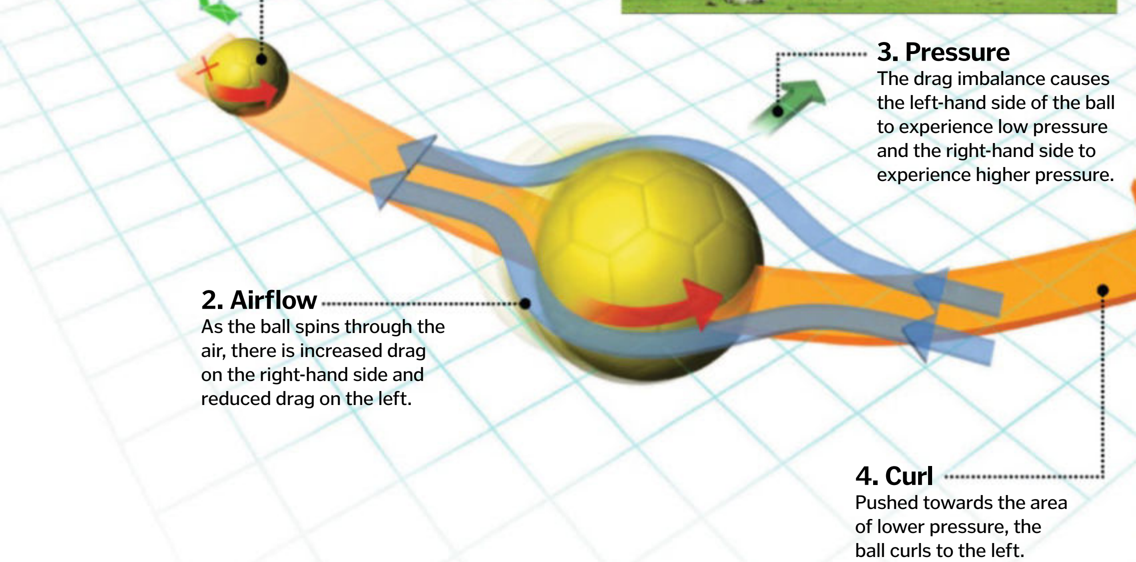
Why footballs can be too round

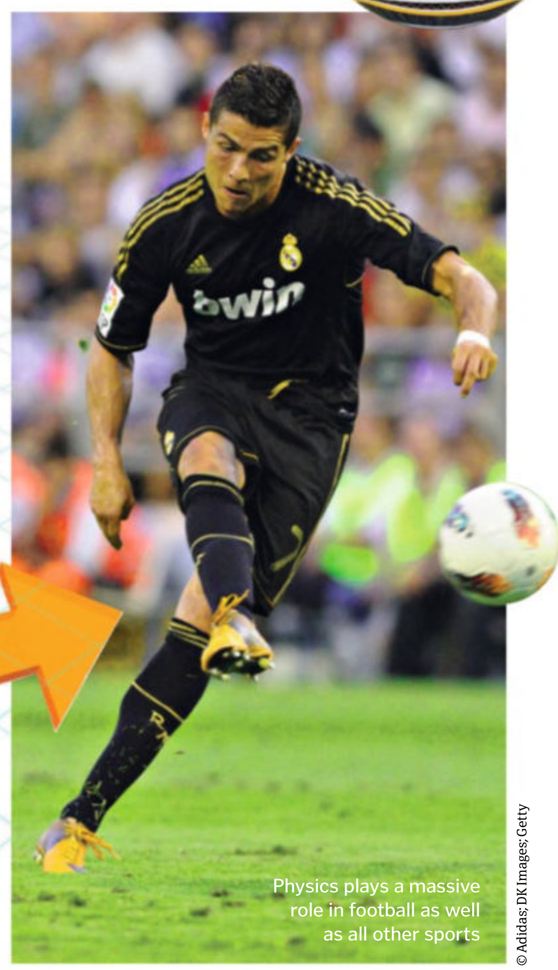
The official match ball for the 2010 World Cup in South Africa, known as the Jabulani, caused consternation with goalkeepers and strikers alike. The lack of panels on the ball and the use of internal stitching made it the roundest ball ever. However, the roundness of the ball caused a lot of confusion among players because of its completely unpredictable swerving. Outfield players didn't like it because the lack of imperfections meant less grip between ball and foot, meaning that they struggled to impart spin on the ball. Meanwhile, goalkeepers couldn't anticipate the trajectory because it would have a habit of suddenly slowing mid-flight or ballooning up, a bit like a plastic inflatable ball.

David Beckham made the art of the free kick one of his specialities

Guide to the curler

How a curling free kick plays out





Physics plays a massive role in football as well as all other sports

"On board the International Space Station gravity is only around ten per cent weaker than on Earth's surface"

Zero-g science

Learn about the physics behind weightlessness and how it affects the human body in space

Also known as weightlessness, zero gravity is experienced in space stations and satellites, as well as for short periods in vacuum shafts and aircraft on a certain flight path (see the boxout below).

The term 'zero gravity' is actually misleading and is more appropriately called microgravity as the force is prevalent throughout the universe, albeit to varying degrees. For example, it is what keeps the Moon orbiting our world, and the reason Earth and all the other planets circle the Sun. Remarkably, on board the International Space Station (ISS) gravity is only around ten per cent weaker than on Earth.

While it may seem as if astronauts and objects have become so light they are floating, their mass is no different than when on terra firma. Essentially, they are all in a synchronised state of freefall – where the only force acting on them is gravity. Like the space station itself, everything in Low Earth Orbit (LEO) is falling around our planet at an equal rate, drawn by Earth's gravitational pull. In fact, every object is on its own individual orbit (just like the Moon) – hence why these physics apply whether someone is inside a space station or outside during a spacewalk.

A good way to grasp how weightlessness works is by imagining yourself in an elevator. As the lift travels down we experience a tiny reduction in weight, as the car is moving *with* gravity, while going up we gain what is called 'apparent weight' because of the additional force exerted by the floor accelerating *against* gravity. Should the lift cable snap, gravity will be the only force at play. As a result, both you and the car will fall at the same rate – 9.8 metres (32.2 feet) per second squared – so for the duration of the drop, you would 'float' in midair.

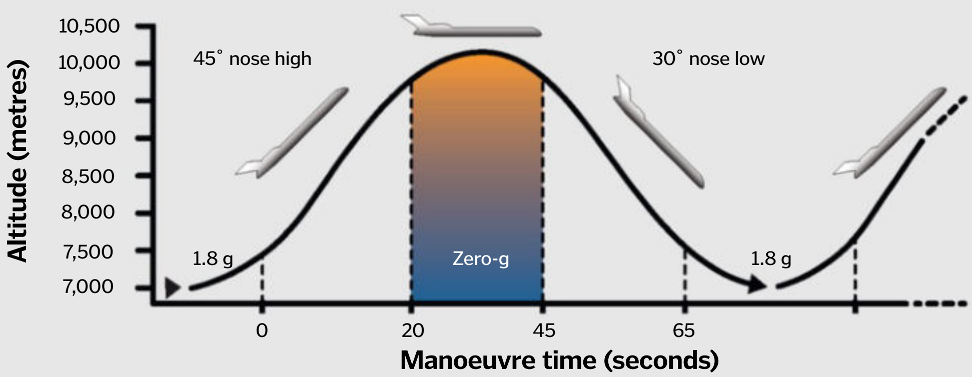
Handily for astronauts in training, there are ways to re-create the sensation of weightlessness here on Earth. NASA boasts the most advanced technology, which involves a vacuum-pumping process that lowers the pressure inside a building so objects can freefall for just over five seconds.

Theories suggest it takes the human body around 40 days to adjust to microgravity, which explains the frequent feelings of nausea when exposed to weightlessness.

In this state, many changes occur to the body. Among other things, there has been reported weakness, loss of balance and, most severely, a reduction in bone calcium. This raises concerns over how long humans can spend outside Earth's atmosphere and scientists continue to scrutinise all astronauts returning from missions for any physical damage.

Re-creating weightlessness on a plane

Described as 'a space adventure open to the public', the G-Force One plane operated by the Zero Gravity Corporation goes through 15 parabolic arcs during its journey between 7,300-10,360m (24,000-34,000ft). Passengers experience 1.8 times their own weight in gravity at the start of the climb but are then shifted to microgravity and weightlessness at the arc's peak. This is the effect of centrifugal force being exerted on the plane but the zero-g periods only last for about 25 seconds.



AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Witness zero-g in action on the G-Force One!

www.howitworksdaily.com

DID YOU KNOW? *Russian cosmonaut Sergei Krikalev set a new record for most time spent in space in 2013 at 803 days*

ESA astronaut Andre Kuipers watches a water blob float freely aboard the ISS. In the reduced gravity environment, surface tension is the dominant force

The story of Oil

Follow oil's fascinating journey from deep underground to a petrol pump near you

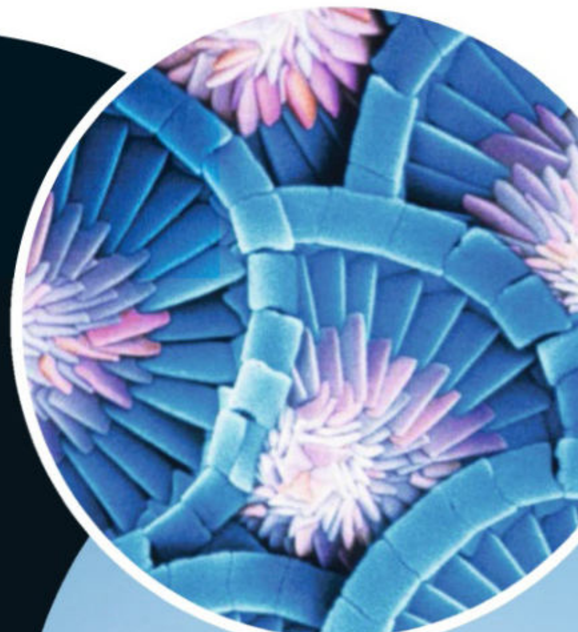
We're all addicted to oil. The fuels on which our cars run, the medicines we take and the plastics we use every day are derived from crude oil. Few of us ever come into direct contact with it, yet it forms the foundations of modern society.

The oil industry took its first steps in the 19th century, driven by the popularity of kerosene-fuelled lamps, but with the advent of the internal combustion engine demand for this energy-dense fuel truly boomed. Humans across the globe now consume 90 million barrels (14.3 billion litres/3.8 billion gallons) of 'black gold' every day.

The story of oil, however, began much longer ago. Crude oil is a fossil fuel formed over millions of years. The process kicked off in prehistoric seas 400 million years ago. As micro-organisms like plankton died, their remains accumulated on the seabed, gradually forming rock. Buried under layers of sediment, the increasing pressure and temperature allowed bacteria and chemical reactions to transform organic matter, first into kerogen and then oil. Collecting in reservoir rock, this oil sometimes got sandwiched between solid rock, creating the oilfields we drill today.

For oil to form, the temperature, determined by the depth at which the source rock is buried, must be just right. Below 80 degrees Celsius (176 degrees Fahrenheit) the organic matter remains kerogen, while above 120 degrees Celsius (248 degrees Fahrenheit), natural gas hydrocarbons develop instead. The exact temperature dictates which hydrocarbons are produced, giving oil from each location its own unique fingerprint.

Three conditions are essential for an oilfield to form. First, a source rock rich in organic material must be buried at the right depth. Then a porous reservoir rock is necessary for it to accumulate. Finally, an impermeable 'cap rock' must prevent oil from escaping to the surface. Predicting where all three conditions may be met allows geologists to pinpoint likely locations for oilfields. ▶



In these cliffs you can see the layers of bituminous shale where oil would have once accumulated (grey) and calcium-rich mudstone (orange); above are coccospheres, one of the millions of tiny marine organisms which decompose to form oil

Inside oil

Oil is a mixture of hydrocarbons – molecules composed of only hydrogen and carbon. It also contains small amounts of oxygen, nitrogen, sulphur, salts and water. The covalent bonds between carbon and hydrogen atoms lock away chemical energy reserves that are freed up when burned. Each molecule has different properties depending on structure and length, making oil a very versatile substance. A short molecule, such as methane (CH_4), is a gas at surface conditions, while longer-chain hydrocarbons are liquids or solids. By selecting and cross-linking hydrocarbons, many different products can be made, from plastics to lubricants.

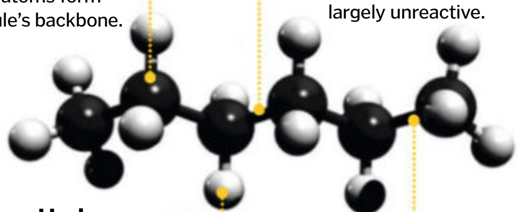
ON THE MAP

Worldwide oil reserves (barrels)

1. Venezuela 298 billion
2. Saudi Arabia 268 billion
3. Canada 173 billion
4. Iran 155 billion
5. Iraq 141 billion
6. Kuwait 104 billion

Hydrocarbon structure

Hexane belongs to the alkane family, one of the most common hydrocarbon types in crude oil



Carbon Six carbon atoms form the molecule's backbone.

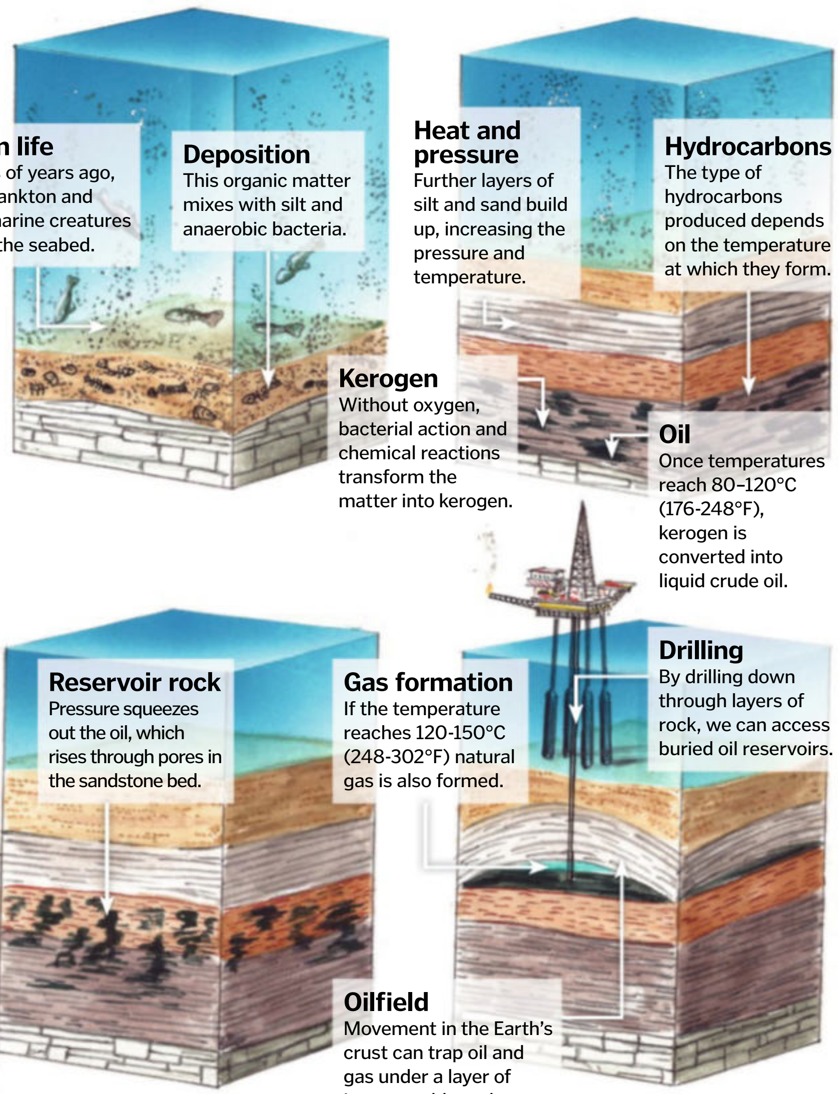
Bonds Single covalent bonds make the molecule largely unreactive.

Hydrogen 14 hydrogen atoms are connected to the carbon atoms.

Combustion Burning hexane breaks these bonds, which creates CO_2 and water.

Oil in the making

See how oil is created in a process spanning millions of years



Ocean life Millions of years ago, dead plankton and other marine creatures sink to the seabed.

Deposition This organic matter mixes with silt and anaerobic bacteria.

Heat and pressure Further layers of silt and sand build up, increasing the pressure and temperature.

Hydrocarbons The type of hydrocarbons produced depends on the temperature at which they form.

Kerogen Without oxygen, bacterial action and chemical reactions transform the matter into kerogen.

Oil Once temperatures reach 80–120°C (176-248°F), kerogen is converted into liquid crude oil.

Reservoir rock Pressure squeezes out the oil, which rises through pores in the sandstone bed.

Gas formation If the temperature reaches 120-150°C (248-302°F) natural gas is also formed.

Drilling By drilling down through layers of rock, we can access buried oil reservoirs.

Oilfield Movement in the Earth's crust can trap oil and gas under a layer of impermeable rock.

▶ The industry uses a variety of techniques to sniff out oil deposits. First, geologists use aerial photography to gather clues on underground rock formations. Measuring the Earth's gravitational pull can also reveal tiny variations that hint at the density of the rocks. Next, a seismic survey is carried out. By firing acoustic waves into the ground and measuring how they bounce off rocks deep underground, a 3D subsurface map is created. Once scientists have located potential oilfields, drilling preparations begin.

Setting up drilling structures on land is fairly straightforward, but at sea, operators must contend with high winds, waves and currents. In shallow waters, jack-up rigs are most common, stabilised by legs that extend down to the sea floor. Beyond depths of 100 metres (328 feet), semi-submersible rigs are towed out and held in place with anchoring systems. Finally, drill ships access the deepest locations. Back on terra firma, rotary drills are most common, using a derrick to raise and lower the drill bit into the ground.

With drilling underway comes the moment of truth: is there any oil? And is there enough to make extraction financially viable? As test wells are dug, scientists retrieve samples that reveal the structure of the rock formation and how much oil is present. Other instruments are lowered down to measure properties, such as the radioactivity or resistance of the reservoir and the pressure and temperature of the gases and liquids. If there isn't enough oil, it's time to pack up and go home. Otherwise, production can begin. In the case of offshore sites, this means replacing mobile drilling units with a permanent oil platform.

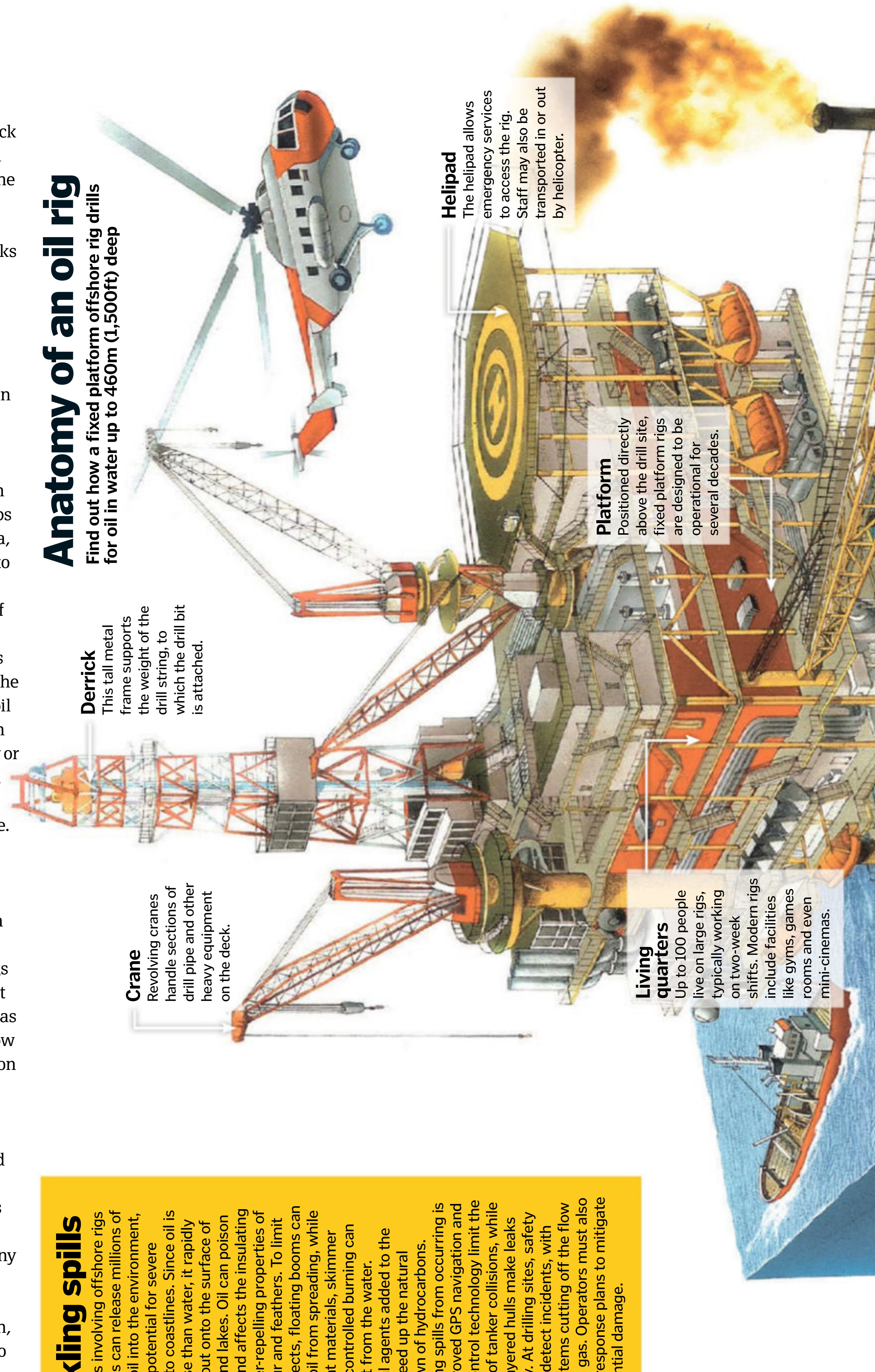
As drilling progresses, cement casing is put in place to keep the hole from collapsing. Highly pressurised pockets of gas or oil can damage rigs and cause explosions or oil spills. To balance out this pressure, a heavy mix of minerals – known as 'mud' – is poured into the hole. Valves called blow out preventers are also fitted under land rigs or on the seabed to seal off the drill line.

When drilling reaches its final depth, a perforating gun makes holes in the casing that will allow oil to enter a narrow pipe. Acid is used to create channels in limestone rock and high-pressure fluid can be used to widen cracks in sedimentary rock. Initially, the oil's pressure may be enough to drive it to the surface, but many other techniques squeeze out the remaining drops. First, waste water is pumped down to build up pressure and keep the oil flowing. Then, steam, gases and other chemicals are injected to make sure no oil is left behind.

The most challenging steps are now over, but crude oil still needs to be refined before it's used and transported to the people who need it… ▶

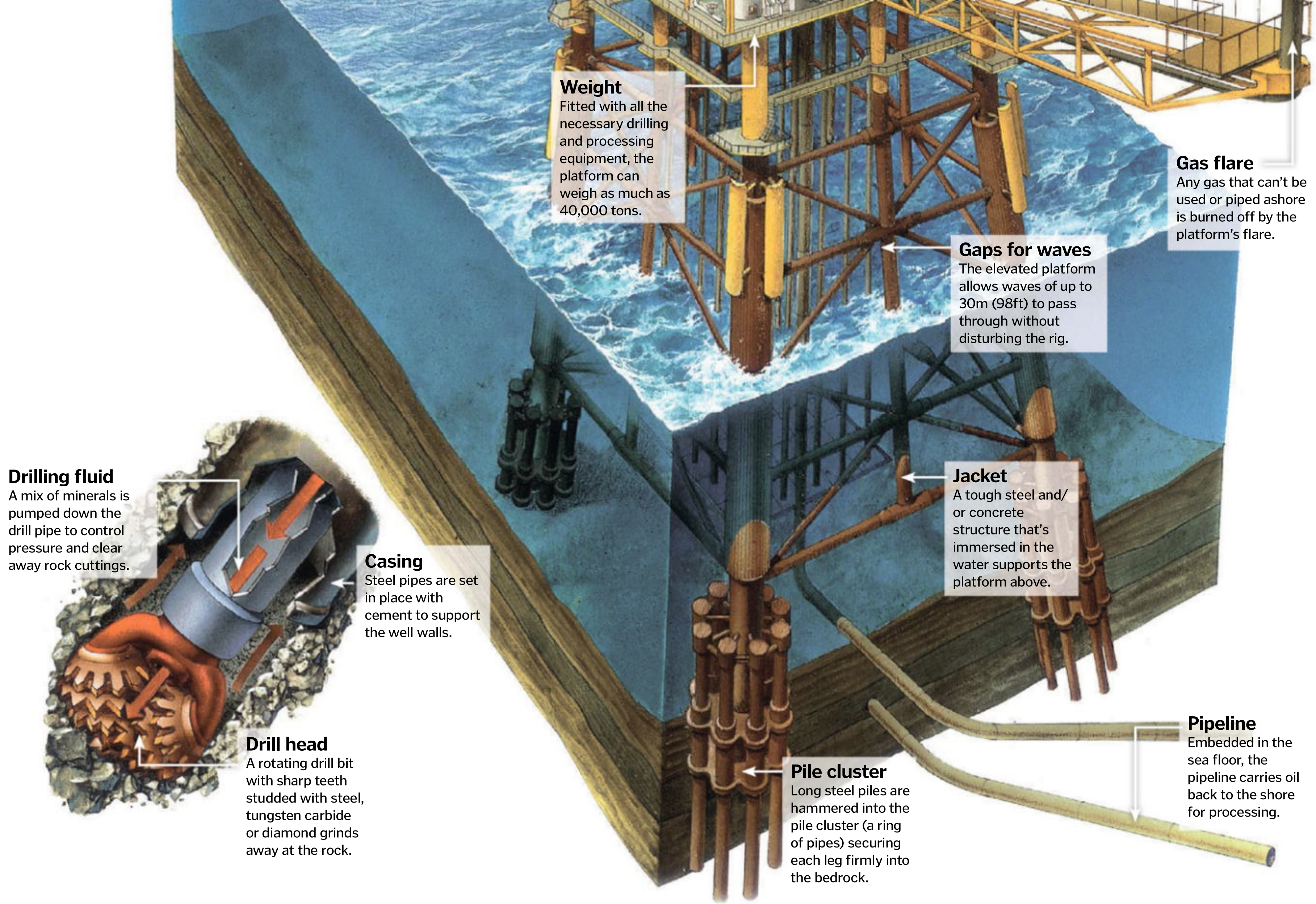
Anatomy of an oil rig

Find out how a fixed platform offshore rig drills for oil in water up to 460m (1,500ft) deep



Tackling spills

Accidents involving offshore rigs or tankers can release millions of litres of oil into the environment, with the potential for severe damage to coastlines. Since oil is less dense than water, it rapidly spreads out onto the surface of oceans and lakes. Oil can poison wildlife and affects the insulating and water-repelling properties of animal fur and feathers. To limit these effects, floating booms can prevent oil from spreading, while absorbent materials, skimmer ships or controlled burning can remove it from the water. Biological agents added to the water speed up the natural breakdown of hydrocarbons. Preventing spills from occurring is key. Improved GPS navigation and traffic control technology limit the chances of tanker collisions, while double-layered hulls make leaks less likely. At drilling sites, safety systems detect incidents, with valve systems cutting off the flow of oil and gas. Operators must also develop response plans to mitigate any potential damage.



Three other types of oil rig

Pump jack

Pump jacks are the most widespread pump design found inland. Converting a motor's rotary movement into the see-saw motion of a beam, the pump jack dips a plunger in and out of the well to draw out oil. Although simple, reliable and easy to install and maintain, pump jacks need to be adjusted manually as the oil pressure fluctuates.

Semi-submersible

Used for mobile drilling and production alike, semi-submersibles rest on two massive hulls. Once the vessel has been towed into its drilling position, the crew fill the balancing hulls with water, allowing them to sink beneath the surface to stabilise the platform above. Semi-submersibles can easily be moved from one site to another.

Spar platform

A spar platform sits upon a cylindrical hull extending 200 metres (656 feet) underwater. Although it is still far above the seabed, the hull's weighted base keeps the platform upright. Further cables moored to the sea floor offer extra stability. Although costly to build, spar platforms can access the deepest sites, down to 3,000 metres (10,000 feet).


Distillation columns tower above a combined oil and gas refinery

▶ Oil extracted offshore is carried to dry land either via pipeline or aboard oil tankers. Crude oil tankers are among the largest ships in the world, some able to carry up to 3 million barrels (477 million litres) of oil. Carrying a highly flammable and corrosive cargo, preventing accidents is vital. Exposed to oxygen, oil vapours create a highly explosive mix. To avoid this, inert gas is pumped into the cargo tanks to keep oxygen levels down.

Pipelines consist of plastic or metal tubes laid on or under the ground or water, with diameters typically from 25-122 centimetres (10-48 inches). Gathering pipelines collecting the oil from wells may be just a few hundred metres long, while transmission lines relaying oil products to consumers can cover many thousands of kilometres. Crude oil or refined products are injected at the initial supply station, with pump stations along the way keeping the oil in motion. Automated probes known as 'pigs' travel down the pipeline, using ultrasound or electromagnetic waves to monitor for damage that could cause leaks.

Although pipelines are generally the most economical form of transport, oil trains sometimes carry oil over long distances. A spate of recent accidents caused by derailments has led to tighter regulations for crude oil trains, including more frequent inspections of vehicles and tracks and stronger braking systems.

The first stop on crude oil's journey to the petrol pump is the refinery. There are hundreds of different hydrocarbons in crude oil, and it is fairly useless until its main constituents have been separated into fractions and processed into different products such as petrol, motor oil or other useful chemicals.

The refining process kicks off with distillation, made possible because hydrocarbon molecules have different boiling points depending on their size and structure. Heated oil forms a vapour that cools as it ascends through a tall distillation column. Longer, heavier molecules condense out first, near the bottom of the column, while light molecules with low boiling points rise to the top. Condensing the vapours at each level gives rise to the full range of oil fractions, from light gases to heavy residual tar and waxes.

Next, chemical processing converts hydrocarbons into the most useful products. The highest demand is for petrol to keep our planet's cars, trucks and other vehicles on the road, so many treatments focus on maximising the amount of petrol and diesel produced. Cracking uses heat to break up larger hydrocarbons into smaller, lighter ones. The opposite process, combining smaller molecules

From refinery to petrol pump...

Oil's journey from well to tank is anything but straightforward

1. Refinery
Refined oil products are purchased by wholesalers and made ready to leave the refinery.

2. Pipeline
Refined products are usually transported by pipeline, with many different products travelling in batches.

3. Transmix
Where two batches have mixed, the resulting 'transmix' is sent back to the refinery for reprocessing.

4. Pumps
Powerful pumps located every 50-80km (30-50mi) push the oil along.

5. Storage terminal
Petrol and other products await distribution in a storage terminal.

6. Tanker truck
Compartments inside the truck allow it to carry various grades of petrol and diesel.

30mn CALORIES IN A GALLON OF OIL

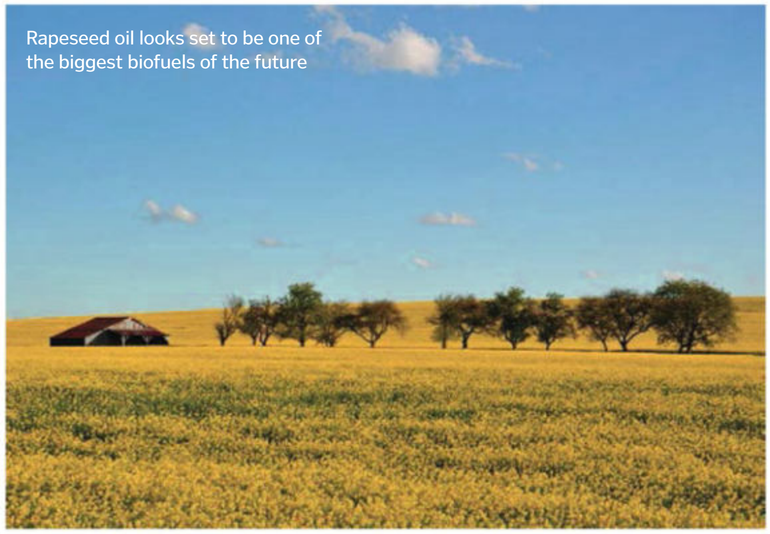
17,000,000,000 LITRES OF PETROL USED EVERY YEAR IN THE UK

4 LITRES OF JET FUEL USED PER SECOND BY A BOEING 747

120,000 NUMBER OF PETROL STATIONS IN THE USA

8km/h AVERAGE SPEED OF OIL TRAVELLING IN A PIPELINE


Oil is transported on some of the biggest ships in the world


Rapeseed oil looks set to be one of the biggest biofuels of the future

to form big ones, is called unification. Finally, alteration is a process which transforms the structure of molecules. For example, alkylation reacts two low molecular weight compounds in the presence of a catalyst to produce high-octane hydrocarbons, which can be blended into petrol to reduce engine knocking.

Once impurities such as sulphur, nitrogen, oxygen, water and other trace substances have been removed, the refinery can then recombine fractions into ready-to-use materials.

Petrol and other products finally enter the pipes that will deliver them to the millions of homes and businesses where they are needed.

While oil supplies are running low, it is unlikely that we will ever extract the last drop of our planet's reserves. Instead, experts predict that oil prices will continue to rise over the next few decades until we reach the point where other energy sources are more attractive. We've already exhausted many of the most conveniently located and easily exploitable oil reserves, leaving increasingly challenging environments such as deep-sea beds or oil sands where extraction comes at a higher cost.

In a post-oil society, electric cars may replace petrol or diesel-fuelled models. These could charge up on electricity produced by renewable sources such as wind, water or solar power, or draw energy from portable fuel cells. We may also fill up our tanks with biofuels produced from vegetable oils, animal fats or algae. Such fuels could help to address climate change concerns by reducing our carbon emissions. Plant oils could also form the raw materials for bio-polymers and other molecules that will replace the plastics and other essential chemicals we currently obtain from crude oil.

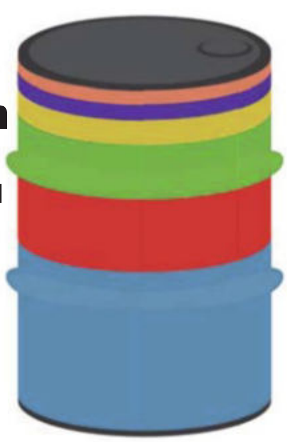
An oil-free world will look very different from today's, but developing the key technologies to wean us off oil now will ensure that the transition is smoother in the future.

8. Petrol station
The end of most oil's journey. In the engine, a spark triggers a small explosion to drive pistons that power our cars.

7. Local distribution
Tanker trucks distribute petrol to filling stations but airports may have a direct pipeline.

£0.03
AVERAGE PRICE OF A LITRE OF PETROL IN VENEZUELA

Crude oil barrel breakdown



- 3.9% asphalt
- 5% heavy fuel oil
- 5.8% jet fuel
- 15.2% other
- 27.4% diesel
- 42.7% petrol

Source: Statistics Canada

Fractional distillation

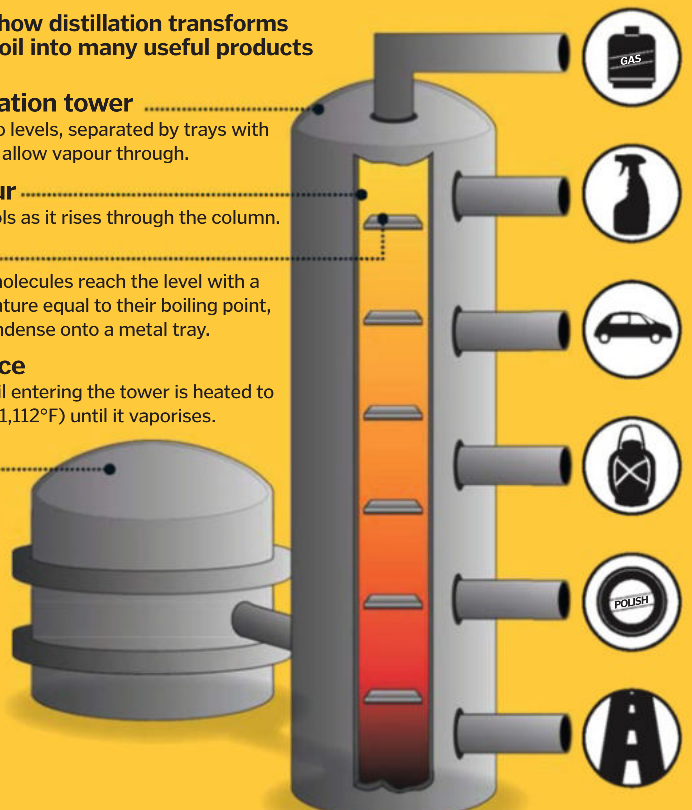
Learn how distillation transforms crude oil into many useful products

Distillation tower
Split into levels, separated by trays with holes to allow vapour through.

Vapour
This cools as it rises through the column.

Trays
When molecules reach the level with a temperature equal to their boiling point, they condense onto a metal tray.

Furnace
Crude oil entering the tower is heated to 600°C (1,112°F) until it vaporises.



Liquefied petroleum gas
This light fuel can be used as a method of heating food or homes.

Naphtha
A highly flammable liquid that can serve as a solvent. It can be used as a burning fuel or for cleaning fluids.

Petrol
About half of the crude oil is converted into petrol, which is used to power most of our vehicles.

Paraffin
This hydrocarbon has a lower igniting point than most other fuels, making it ideal for lamps and stoves.

Lubricating oils
Helping to stop moving parts from wearing, it can also be used for waxes and some types of polish.

Bitumen
Also called tar, this heavy material solidifies quickly to provide a waterproof layer for roofs and roads.

ARTIFICIAL INTELLIGENCE

THE GREATEST CHALLENGES WE FACE IN MAKING COMPUTERS THINK LIKE US

Intelligence is a tough concept to pin down. Is someone, or something, intelligent because they can multiply 29 x 18 in their head? What about emotional intelligence – working out if someone is sad, angry or faking an emotion? There's a fair few people who could solve the above sum (it's 522, if you were wondering) but wouldn't have a clue what to do when someone starts bawling their eyes out in front of them. All this makes the field of artificial intelligence a thorny path to tread.

British mathematician Alan Turing, most famous for his codebreaking work at Bletchley Park during World War II, got people thinking about computers as a tool for thought, rather than mere calculations. But where are we now in terms of creating computers and robots that can think, talk and perform tasks like humans? After recent advances in drone and interactive robot technology we are close to a breakthrough in AI, but have a little way to go yet before engineering a Samantha from *Her* or Skynet in *Terminator*.

Oxford University's professor of Computer Science, Nando de Freitas, has spent a lot of time studying the brain, trying to work out what goes on without us knowing it: "There's an area in the brain called the hippocampus, which is fascinating. In a rat, particular neurons will fire when it is travelling in a certain direction, but only for that direction. However, if it is in a different part of the room, a different neuron fires. That is how the rat knows where it is in the room. Each neuron is connected to the visual cortex,

5 TOP FACTS
AI LABS

CSAIL
1 The Computer Science and Artificial Intelligence Lab at MIT in Boston is one of the world's leading AI hubs, with 28 labs dedicated to artificial intelligence research alone.

Aldebaran
2 Commercial robot technology company Aldebaran is responsible for the creation of NAO, an advanced humanoid robot that can play games and interact with people.

Stanford AI Lab
3 Founded by AI pioneer John McCarthy in 1962, this lab at Stanford is dedicated to pushing technologies that will benefit humanity in its future progress.

Quantum AI Lab
4 A collaboration between Google and NASA, QuAIL focuses its research on developing a completely new kind of intelligence using quantum computers.

Facebook's AI Lab
5 NYU professor Yann LeCun is the director of Facebook's AI Lab, aimed at building on Deep Learning research to enhance understanding of its massive global user base.

DID YOU KNOW? *The supercomputer Watson was named after IBM founder Thomas J Watson*

where we store images, and the auditory cortex, where we store sequences. Each neuron represents a location in the world and fires when you are there. Every time you excite a neuron in the hippocampus, it fires a certain set of neurons representing an image in the world, meaning, for example, you can now imagine your way home. Right now, we are trying to work out how to do that. We take intelligence for granted. You aren't aware of a lot of what's going on in your brain, which is why it's so hard to reverse engineer it."

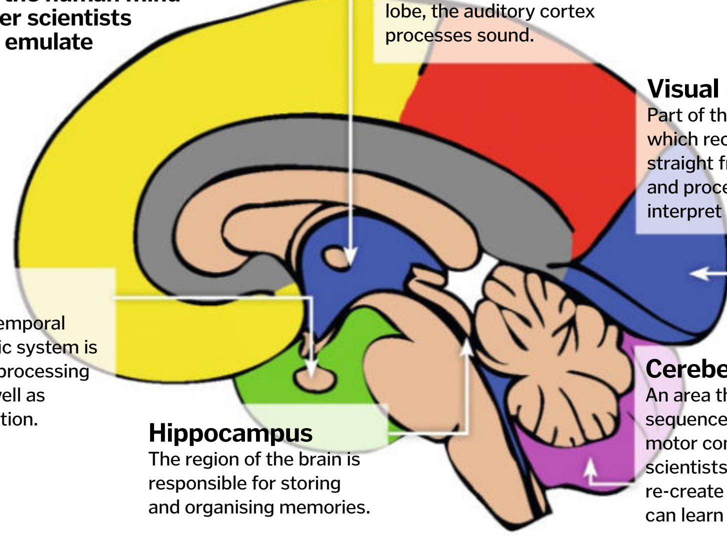
The argument that a robot is unable to be truly intelligent until it can feel emotions like a human is easy to refute. "Emotions are one of the easiest things to reproduce," argues De Freitas. "You don't need to build something as intelligent as a human to get an emotional response. If you were to poke the amygdala with a needle, you'll get an emotional response. That's because the amygdala is part of the old brain, which we share with rats, mice, cows, pigs and lots of other animals. The new brain – areas like the neocortex – is where we do our higher level of thinking."

So if scientists aren't looking at developing robots that get sniffly at *The Notebook*, how are they attempting to create the next generation of thinking robots? After all, we have had Deep Blue, the computer that defeated chess world champion Garry Kasparov in a duel, and Watson, the supercomputer that thrashed two champions in *Jeopardy!* What hurdles are they yet to overcome?

"I see intelligence as being able to interact with an environment and do the right thing," continues De Freitas. "Humans are able to plan their actions and engage in counterfactual reasoning, which is a fancy way of saying 'what if' reasoning. That is being able to perform an action and ask yourself: 'What would happen if I did ▶

Around the brain

Key areas of the human mind that computer scientists are trying to emulate



Auditory cortex
Found in the temporal lobe, the auditory cortex processes sound.

Visual cortex
Part of the neocortex, which receives images straight from the retina and processes them to interpret what we see.

Amygdala
Found in the temporal lobe, this limbic system is involved with processing emotions as well as memory retention.

Hippocampus
The region of the brain is responsible for storing and organising memories.

Cerebellum
An area that stores sequences, crucial for motor control. AI scientists want to re-create this so robots can learn journeys.

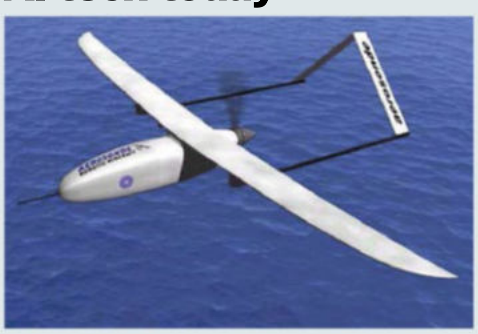
Despite struggling with some shorter clues, Watson easily beat its human rivals

Brain games

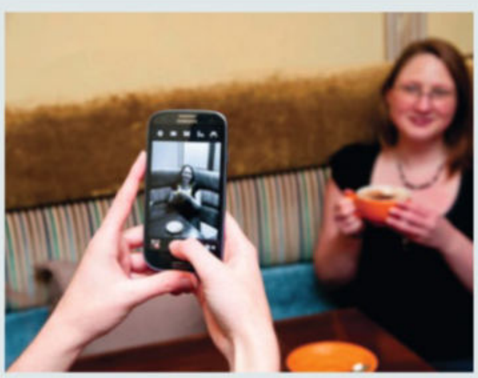
Deep Blue and Watson are amazing examples of supercomputers that were able to defeat the best human practitioners in chess and quiz show *Jeopardy!*, respectively. But what tech went into the duo? Deep Blue beat world chess champion Garry Kasparov in 1997, using its ability to assign values to the various pieces on the board and analyse 200 million moves per second using its AIX operating system and IBM SP Parallel System.

Watson came 14 years later and stunned the world by not only being able to understand the complex questions posed, but formulate a logical response from its stored database in seconds. In order for this incredibly powerful machine to work, Watson used 90 IBM Power 750 computers, which were the same as 2,800 high-speed computers, housing 15 trillion bytes of memory. Interestingly, IBM has recently announced a competition to push developers into incorporating Watson's intelligence into mobile apps.

AI tech today



Drone aircraft
Unmanned aerial vehicles (UAVs) first emerged in the early-Fifties and can be used in warfare, reconnaissance, aerial mapping and scientific research. New technology allows UAVs to plot their own route without human intervention.



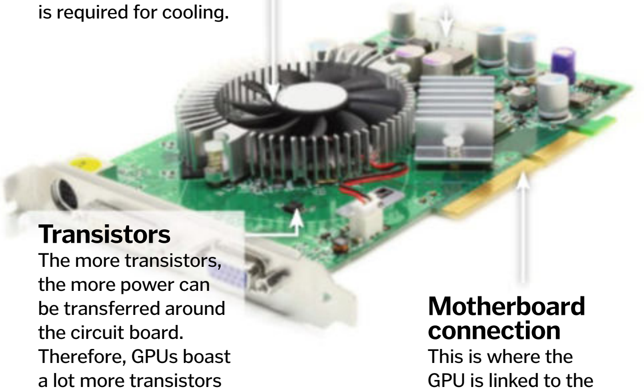
Phones & tablets
The most obvious bit of AI technology in your smartphone or tablet is in the camera. Facial recognition, allowing for easier focusing and tagging, is a real leap forward in intelligent image-capturing technology.

Advanced toy robots
Created by Aldebaran, NAO is an advanced humanoid robot. It can walk on a variety of surfaces, recognise images and faces, work out who is talking to it, and even play Noughts and Crosses (Tic-Tac-Toe).

"The AI robot of the future will be an intelligent machine of a different kind, like a rat is different from a human"

Inside a GPU

One of the key ways that robots are able to catch up with humans in terms of raw processing power is by taking advantage of graphics processing units (GPUs). These computer chips are able to deal with more than one task at a time and cope with much bigger data sets than the central processing unit (CPU) that, until now, has been the standard command centre in robots and PCs. If you think of a computer like a rowing boat, the CPU is the cox (the brains of the outfit), while the GPU is the rowing force, providing the raw power to take the load off the cox. CPUs have a small number of cores, designed for sequential tasks, while GPUs have thousands of smaller cores so each can be put to work sifting through data at once.



Processor fan
The sheer number of cores running simultaneously creates a lot of heat, so a large fan is required for cooling.

Memory
Information is stored here, allowing the GPU to process multiple pieces of data at once.

Transistors
The more transistors, the more power can be transferred around the circuit board. Therefore, GPUs boast a lot more transistors than CPUs.

Motherboard connection
This is where the GPU is linked to the machine's mainframe.

this other thing?' Robots are much smarter than us. They can perform logic and mathematical tasks much quicker. However, we can go from observing sequences in the world and build representations of them in our brains. This is what we are now trying to achieve with AI."

De Freitas is heavily involved with the development of Deep Learning, a programme which looks to replicate the human brain's ability to not only see an image but understand it as well – something major technology corporations like Google, Amazon and Facebook are keen to exploit.

"Deep Learning tries to get robots to build representations of the world and operate on those representations to build sequences in their mind. Then we want them to learn to construct different sequences. It's like if you take all the videos on YouTube, cut each video into ten-frame chunks and cut and paste them into new movies. The next step is to imagine alternative scenarios to what is put in front of them. We want computers to learn abstract representation about their environment and then think about their environment and the cause and effect of their actions.

"All the big search engines already use this tech. For Facebook, that means learning about users from all the data they input. You can learn a lot from the data that exists out there – even their IQ. They could use this data to start recruiting, or even become a life coach. No psychologist has ever had access to this amount of data. I talked to Mark Zuckerberg about this a few months ago. There's a reason why he's investing in this."

Google is also taking a close interest in the possibilities AI brings to the table. The company's reported £242 million ($400 million) acquisition of DeepMind, a London-based AI company, and their hiring of notable AI pioneers Ray Kurzweil and Geoffrey Hinton shows that the big players are keen to exploit this emerging technology.

The Google Chauffeur is a self-driving car, which is creating waves in Silicon Valley where executives are testing them out on public highways. Google reports that its cars have collectively driven over 800,000 kilometres (500,000 miles) without a single accident. There were 1,754 fatalities on Britain's roads in 2012 and more than 33,000 in the United States, while a further 145,000 were injured on US highways. De Freitas says that in the near future "cars will be way better than humans at driving." Computers are able to react much quicker than people. Google Chauffeur is able to make hundreds of diagnostic checks per second and only requires serious human intervention every 58,000 kilometres (36,000 miles) on average. Considering that in the UK in 2012, the average distance a person travelled in a year was around 10,800 kilometres (6,700 miles), you would need to drive for five years before having to take any action!

Another near-future application for AI is in the medical industry. Two robots that are already operating in Japan are the RIBA robot, which can lift patients comfortably and take instructions from an operator, and the Actroid-F, a human-like bot that can act as an observer to nurses. But, according to De Freitas, robotic nurses could very soon become a reality. "Robots can do diagnoses much faster than us. Right now, we send patients, including elderly people, home and the nurse only visits every now and again. If you instrumented their home, making sure it was non-invasive, you could train a system to detect when a patient is about to have a lapse so you could send an ambulance in time. It's not something that's enabled yet, but there are a few companies that are working on it."

So artificially intelligent robots are more than capable of performing complex tasks. But what happens when they fall into the wrong hands? "Just as people can use AI in cars to help us drive to work, people can also use AI to drive around and kill people. As someone who works on it and sees it coming, this is a very legitimate concern.

"We already have a lot of aircraft that fly autonomously. It's not a technology of the future. It's here now, so I think there should be a Geneva convention-type agreement to stop people misusing robots. But no, I don't see AI robots rising up and destroying us. If anything, I see them rising up to stop us killing each other.

"The AI robot of the future will be an intelligent machine of a different kind, like a rat is different from a human. They won't be human, because what makes us human is different from what makes a piece of silicon human."

AI in videogames

As many gaming devices now use GPUs as their processing chip, videogames are able to make use of the increased power and human-like thinking of NPC protagonists and antagonists. *Alien: Isolation* by Creative Assembly revisits the *Alien* film franchise and has you play as Ripley's daughter Amanda, trying to escape from the alien on board the Sevastopol space station. The alien doesn't run along a predetermined path, instead reacting to the player's behaviour. Not only that, but it learns whether you are a 'hider' or a 'runner'. The advanced game engine has the ability to make instantaneous decisions, thanks to a GPU that can make a lot of decisions at once, rather than rely on the CPU to make a series of linear decisions.

Also making the most of AI technology are fighting games like *Tekken 5: Dark Resurrection*. In the Yurin Dojo, you are able to battle a 'ghost character' in which you fight an opponent based on the combat style of another player. All the time you are playing the game, it gathers info about your fighting style in order to re-create you as one of the in-game characters!

AI tech in *Alien: Isolation* allows the enemy to adapt to your gameplay strategy

KEY DATES
HISTORY OF AI

1642 French mathematician Blaise Pascal invents a device that helps his taxman father add and subtract numbers.

1936 Alan Turing invents the Turing Machine – a theoretical computer that follows a set of directions.

1956 The first recorded use of the term 'artificial intelligence' is by John McCarthy, proposing a conference on the subject.

2011 IBM's Watson defeats humans in gameshow *Jeopardy!*, requiring unprecedented levels of speech recognition and hypotheses.

2012 Google executives begin testing self-driving cars on public highways.

DID YOU KNOW? *In 2012 a Brazilian researcher estimated that the average human brain has around 86 billion neurons*

Humans vs robots

Who comes out on top in the battle of the brains?

✔ Planning

This is where humans really trump computers. Humans can map out a series of sequences to lead us to a goal. Involving millions of neurons interacting in yet fully understood ways, computers lack this ability for now.

Logic ✔

Computers are extremely linear when it comes to thinking. Because of this – as well as their lack of emotional responses – they can work logically through commands to reach the best possible solution.

✔ Speech recognition

Computers are catching up, but humans still have the edge. Most humans can hear a sentence and extract meaning from it, based on experience and the situation. Few robots are able to do this, though natural language processing, like the iPhone's Siri technology, is constantly improving.

Maths ✔

There's no denying it, computers are geniuses when it comes to doing sums. Just ask your calculator. Again, because base mathematics is the input of data and the extraction of a single solution, a simple programme can work through calculations extremely quickly.

✔ Adapting

Most computers are programmed in a certain way and are only able to react to what they have been taught. Humans have the ability to think creatively about a subject, due to our evolved neocortex, and come up with radical, outside-the-box solutions. Until roboticists are able to replicate the neural connections, we will stay ahead of robots when reacting to novel situations.

Speed ✔

Computers are able to operate at much faster speeds because they are stripped-down basic brains. Just think, even though a Land Rover may have more horsepower than a Ferrari, the latter is faster because it has less weight to hold it back. Similarly, when put to a task, a computer is able to work through a problem quicker, despite a human brain having more processing power.

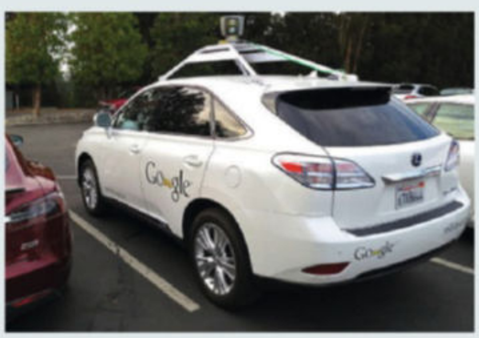
VERDICT

Humans still edge the battle of the mind on multilayered matters, such as forward planning, meaning that creative and on-the-spot thinking are still our forte.

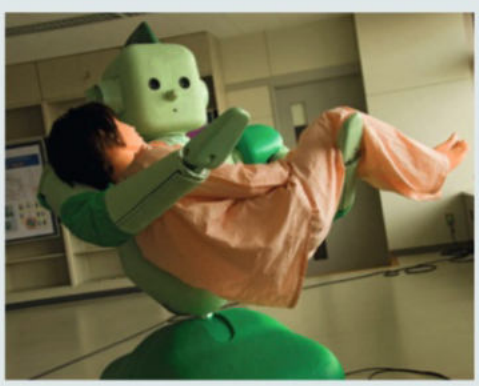
VERDICT

There is simply no matching robots when it comes to pure logic and mathematical problems. If you want to work something out quickly and accurately, ask a robot.

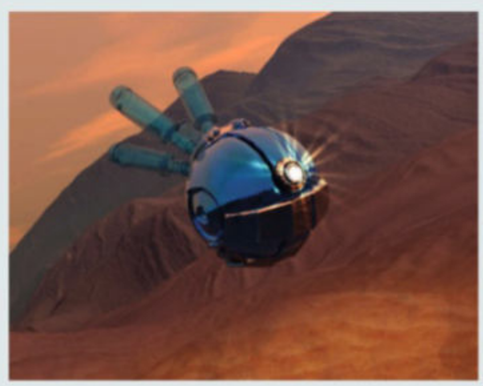
Future AI tech



Self-driving cars
As yet only allowed to be driven in California and currently undergoing testing, this Google driverless car is an exciting pioneer that could herald a new era of transport, using advanced diagnostic tools to look out for hazards.



Robot medics
Machines could keep a watchful eye and run analysis on vulnerable patients faster and with greater accuracy. A trial is currently running at the Memorial Sloan-Kettering Cancer Center in New York, advising on lung cancer treatment.



Space vehicles
Work is progressing on space vehicles with 'human-like brains' that can plot their own route on treacherous planets like Mars by constantly analysing the terrain and making creative decisions, running off GPUs rather than CPUs.

"It's helped in the aftermath of natural disasters and mainly targets diarrhoea and Guinea worm disease"

The lifesaving water filter

How can a simple straw make even the dirtiest water safe to drink?

To this day dirty water is one of the biggest killers on Earth, particularly in the developing world. However, there now exists a cheap and efficient way to stop dangerous, waterborne bugs in their tracks. Enter the LifeStraw.

The device aims to decontaminate dirty water, making it safe for human consumption. It achieves this by using a 0.2-micrometre tube with a hollow fibre membrane that allows water through, but not dirt and virtually no pathogens like parasites and bacteria, of which over 99.9 per cent are blocked.

As the latest iteration of the LifeStraw doesn't use electricity or any sort of chemical (an earlier version used iodine), it is ideal for remote, impoverished areas experiencing drought or with an unreliable water supply. The device can process up to 1,000 litres (264 gallons) before it has to be replaced.

It's already helped in the aftermath of many natural disasters and mainly targets diarrhoea and Guinea worm disease, which are leading causes of death in developing countries.

The LifeStraw aims to reduce the spread of disease by providing clean water to all

LifeStraw up close

See what's happening inside these pocket-sized water filters

Mouthpiece
Safe water is now ready to drink. You just blow air through to clean the straw out and it's ready to use again.

Filtration
Hollow fibres in the tube trap 99.9999 per cent of bacteria and 99.9 per cent of parasites and filter out any soil particles.

Plastic casing
Weighing in at just 56g (2oz), the straw is very practical for distribution and compact enough to carry with you 24/7.

Dirty water
The potentially contaminated water is sucked up at the bottom of the device.

How power showers work

Explore the complex plumbing network usually hidden out of sight which helps wake us up in the morning

1 Cold water mains supply
The journey starts with cold water flowing from the mains to the shower system.

2 Stop tap
Whenever the shower is not being used, the stop tap prevents water flowing into the system and the cistern.

3 Cold water cistern
The last port of call for the mains cold water, the cold water cistern holds the H_2O until it is ready to be added to the hot-water cylinder.

4 Spare cold water supply
As well as feeding into the cylinder, a separate source of cold water is taken straight to the mixer valve. This is used if you fancy a cooler shower and also as a way to increase the pressure.

5 Hot water mains supply
Hot water is drawn directly from your home's heating system. Unlike hot water taken from the cylinder, this mains source guarantees continuous warm water.

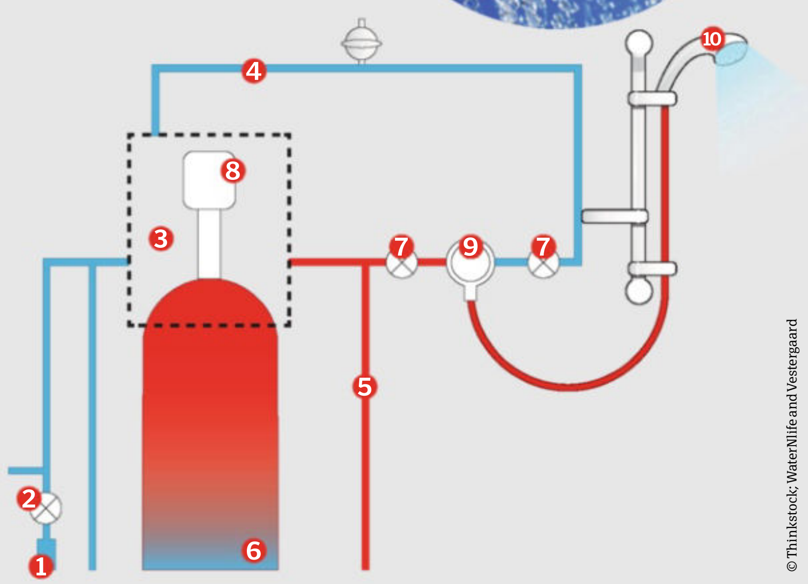
6 Hot-water cylinder
Serves as a storage tank for both hot and cold water. The water is mixed and later set to the desired temperature here.

7 Gate valves
The mixed water is now ready to be used. Valves on either side block the water in the mechanism until the user turns the main dial to start the shower.

8 Pump
This supplies the power to draw water around the system's pipes and changes flow rate according to the pressure setting.

9 Mixer valve
This is the dial you see on the external shower unit which allows you to select the desired temperature and water speed.

10 Shower head
A power shower's main drawback is that it uses up to five times more water than a conventional electric shower. Eco-friendly or low-flow shower heads can be installed for a less water-greedy shower.



KEY DATES
MOWING MILESTONES

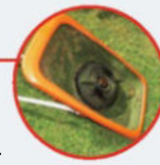
1827
Edwin Budding brings out the first lawn mower, aimed at maintaining sports fields and big gardens.

1859
A new quieter version of the mower is released, which employs a chain rather than a roller to transfer power.

1893
James Sumner patents the first steam-powered lawn mower. Petrol-based mowers quickly follow.

1922
The first ever self-propelled ride-on grass-cutting tractor – called the Triplex – goes on sale in the USA.

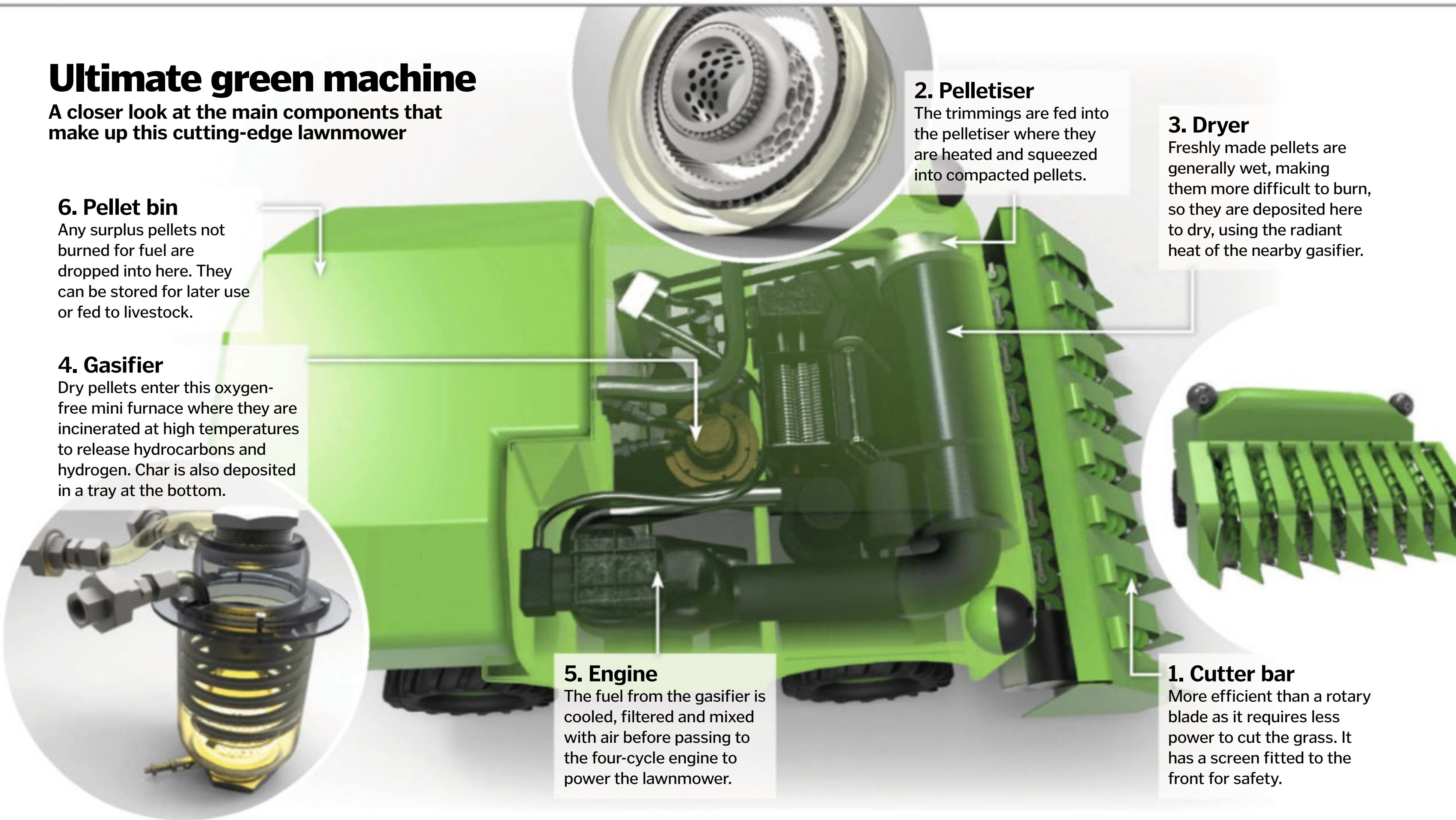
1964
The first Flymo hover mower arrives, using a fan above the blade to generate a cushion of air.



DID YOU KNOW? *As well as being eco-friendly the EcoMow can navigate itself using GPS technology and on-board sensors*

Ultimate green machine

A closer look at the main components that make up this cutting-edge lawnmower



Eco-mowers explained

Meet the 21st-century lawnmowers which have been designed to run off the very same grass cuttings we normally throw away

Invented in the 1820s, the earliest lawnmowers were surprisingly eco-friendly but fairly hard to operate, typically made out of heavy cast iron and with relatively small blades, although some agricultural varieties were bigger and used farm animals for pulling power.

By the time motorised versions rolled up decades later, this situation had reversed. The machines were easier to use but produced petrol fumes detrimental to the environment. Later electric models didn't generate pollution directly, but still relied on fossil fuels, and also came with the risk of electrocution.

Eco-mowers use 21st-century technology to get the best of both worlds: a mower that cuts the lawn by itself with super-green credentials. A cutter bar has replaced the traditional rotary blade, which consumes far more energy in order to keep it spinning. The grass then enters a pelletiser where the loose trimmings are compressed into pellets using a combination of heat and pressure.

The grass pellets then enter a small chamber to be dried and next comes the most crucial component of the eco-mower: the gasifier. Sealed off to prevent oxygen getting in, it subjects the dried-out pellets of grass to extreme temperatures (up to 1,250 degrees Celsius/2,282 degrees Fahrenheit). In a process known as pyrolysis the biomass releases hydrogen and other hydrocarbons, which, along with air, can then be fed into the engine.

All that's left over from pyrolysis is carbon char, which is by no means waste either, as ongoing research is revealing an ever-wider range of applications for it. This includes compression into charcoal briquettes, water treatment and even improving soil quality on overused agricultural land.

Waste power

Grass trimmings are not the only waste product generating power around the world today. Used vegetable oil (UVO) from factories and fast-food restaurants can be processed and used as an alternative to diesel in cars and public transport. In Norway, tons of household rubbish are being incinerated to heat water and generate electricity for areas of Oslo. Perhaps most surprising of all, though, are pioneering projects (like one in Ghana) that are converting sewage into reusable products – including fertiliser and biofuel. It also means less sewage is being dumped into the ocean.

"The real ingenuity of this moving staircase comes in the way the steps flatten at the top and bottom"

How escalators work

Unveiling the mechanics that powers these moving staircases

An escalator is essentially made up of a series of interlocking steps, wheel-mounted on a chain, which in turn is powered by an electric motor.

The real ingenuity of this moving staircase comes in the way the steps flatten at the top and bottom, before splaying out into solid steps for users to stand on.

As the steps are pushed along the rail, they are raised up, each resting against the next. There are two sets of wheels: the first attached to the chain, pulling the steps along, and the second are free, but positioned in such a way as to keep the steps level. As the mechanism reaches the end of the escalator, the chain levels out, and the steps follow suit to make it easier to disembark.

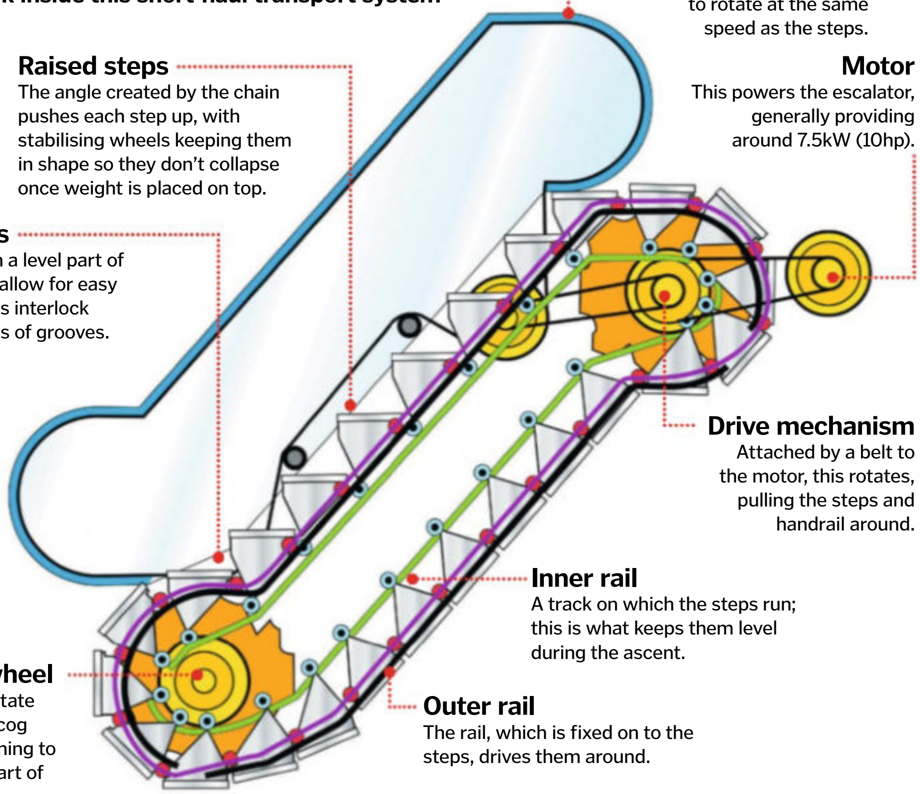
As the steps disappear from sight, they rotate around the drive gear, interlocking through carefully placed grooves. The steps then travel back to the start of the escalator upside down, underneath the visible part of the machine, before starting their journey again.

On the reverse end of the escalator, the steps level out before becoming defined steps again as they ascend the angled chain. The handrail runs off the same drive mechanism, rotating around a stationary rail.

Escalators do not require much power to run; a typical machine needs only a 7.5-kilowatt (ten-horsepower) engine to operate – about the same as three small lawnmowers.

Stairs on the move

Take a look inside this short-haul transport system



Handrail
Uses the escalator's motor to rotate at the same speed as the steps.

Motor
This powers the escalator, generally providing around 7.5kW (10hp).

Raised steps
The angle created by the chain pushes each step up, with stabilising wheels keeping them in shape so they don't collapse once weight is placed on top.

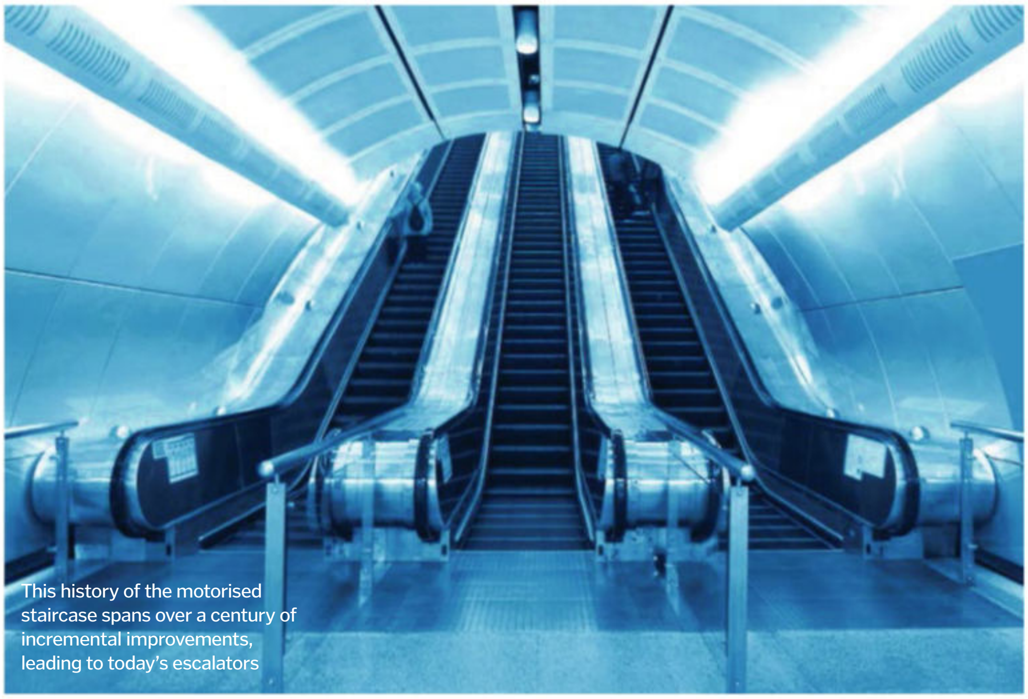
Flat steps
These are on a level part of the chain to allow for easy access. Steps interlock using a series of grooves.

Drive mechanism
Attached by a belt to the motor, this rotates, pulling the steps and handrail around.

Inner rail
A track on which the steps run; this is what keeps them level during the ascent.

Return wheel
The steps rotate around this cog before returning to the visible part of the system.

Outer rail
The rail, which is fixed on to the steps, drives them around.



This history of the motorised staircase spans over a century of incremental improvements, leading to today's escalators

The rise of escalators

Jesse Reno, an inventor hailing from Kansas in the USA, patented the escalator on 15 March 1892. He designed it more as an entertaining novelty, rather than a practical transport system, with the first machine being installed along the famous Old Iron Pier and the amusement park in Coney Island, Brooklyn.

Five years later, however, Charles Seeberger redesigned the moving staircase and installed the first-ever commercial escalator in the Otis Elevator Company's factory itself. Otis bought out the patents of both Seeberger and Reno, positioning the company as the foremost producer of commercial escalators, a status they have held to this day, with their escalators found in shopping centres, airports and train stations all over the world.

"Type 45 destroyers, Typhoon fighter jets and even E-3D Sentry aircraft can be brought together"

Inside battle simulators

A revolutionary new system for training the soldiers of tomorrow

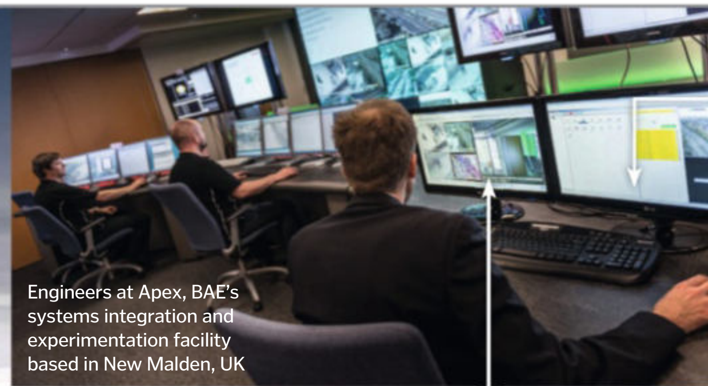
Training recruits to use some of the world's most expensive and complicated military technology is no easy task. Millions of pounds' worth of military hardware needs to be placed in the hands of learners and, while these future fighters are carefully managed, the run-time costs to operate trial mission after trial mission are quite simply astronomical.

After years of development, defence company BAE has created a virtual battle training system – a simulation network that runs through live scenarios with several players simultaneously. Indeed, thanks to the Dedicated Engineering Network (DEN), simulators controlling virtual Type 45 destroyers, Typhoon fighter jets and even E-3D Sentry aircraft can be brought together in a simulated combat environment and put through their paces in a range of scenarios combining land, sea and air tech.

In doing this, not only can the most advanced military hardware be tested together as one functioning unit, but trainees and professionals alike can run through missions without even having to set foot outside.

This not only saves money but also allows for a greater range of scenarios to be played out in a short period of time. Further, thanks to DEN securely managing integration with Ministry of Defence (MoD) networks, scenarios can be witnessed by commanders and decision-makers remotely, granting an unprecedented access to information.

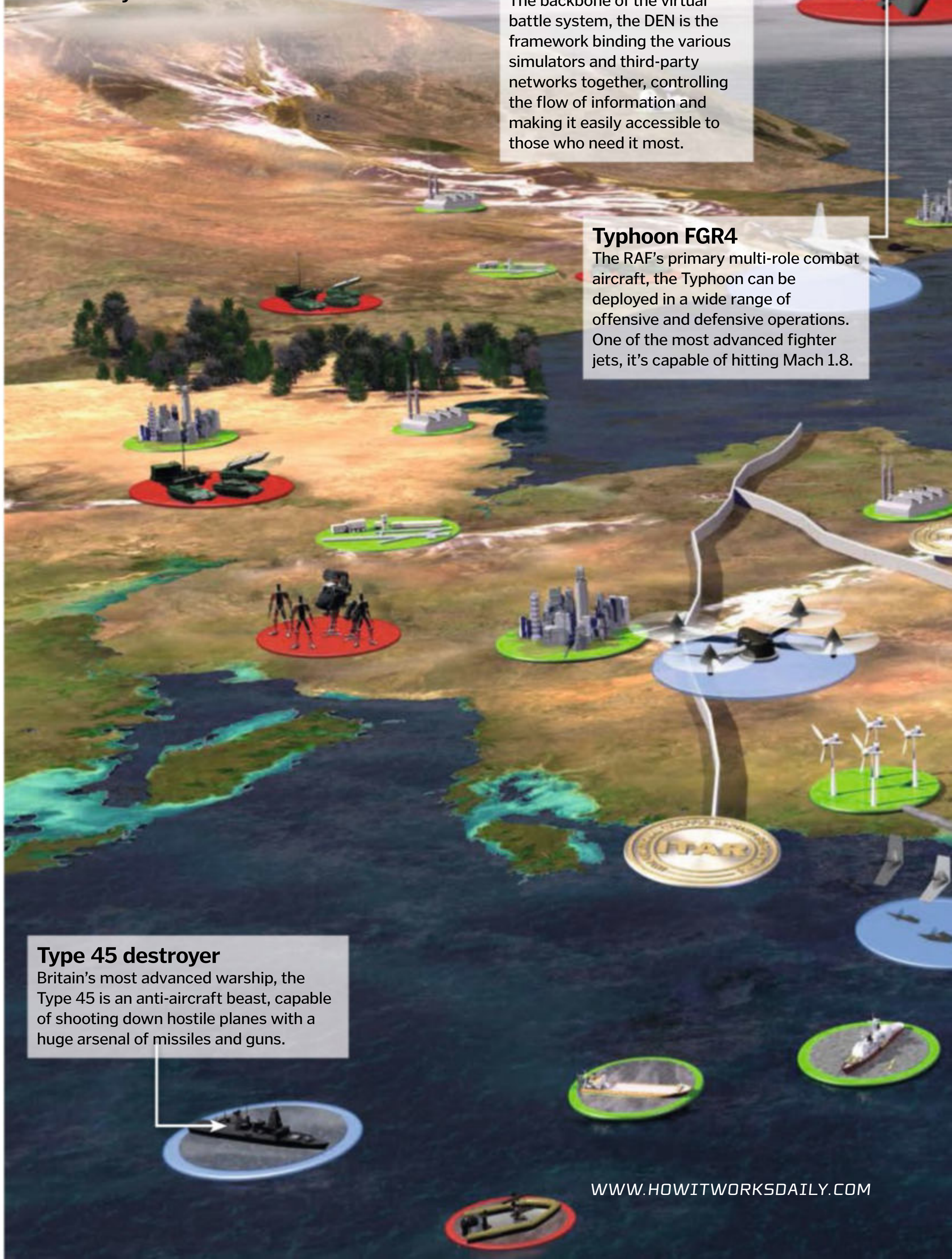
The system is still under testing, with a simulator at BAE's Warton facility in Lancashire, UK, emulating four Typhoons, partnered with two other simulators at different sites which emulate an E-3D Sentry AEW1 and a Type 45 destroyer. With a high level of success to date, more trials are already planned over the next 18 months, with more simulated combat vehicles looking to be integrated – the most notable being the state-of-the-art F-35 Lightning II fighter jet.



Engineers at Apex, BAE's systems integration and experimentation facility based in New Malden, UK

A digital battlefield

Check out the core elements that make up this country-wide combat simulator



Dedicated Engineering Network (DEN)
The backbone of the virtual battle system, the DEN is the framework binding the various simulators and third-party networks together, controlling the flow of information and making it easily accessible to those who need it most.

Typhoon FGR4
The RAF's primary multi-role combat aircraft, the Typhoon can be deployed in a wide range of offensive and defensive operations. One of the most advanced fighter jets, it's capable of hitting Mach 1.8.

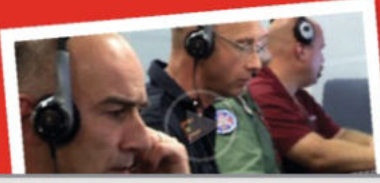
Type 45 destroyer
Britain's most advanced warship, the Type 45 is an anti-aircraft beast, capable of shooting down hostile planes with a huge arsenal of missiles and guns.

AMAZING VIDEO!

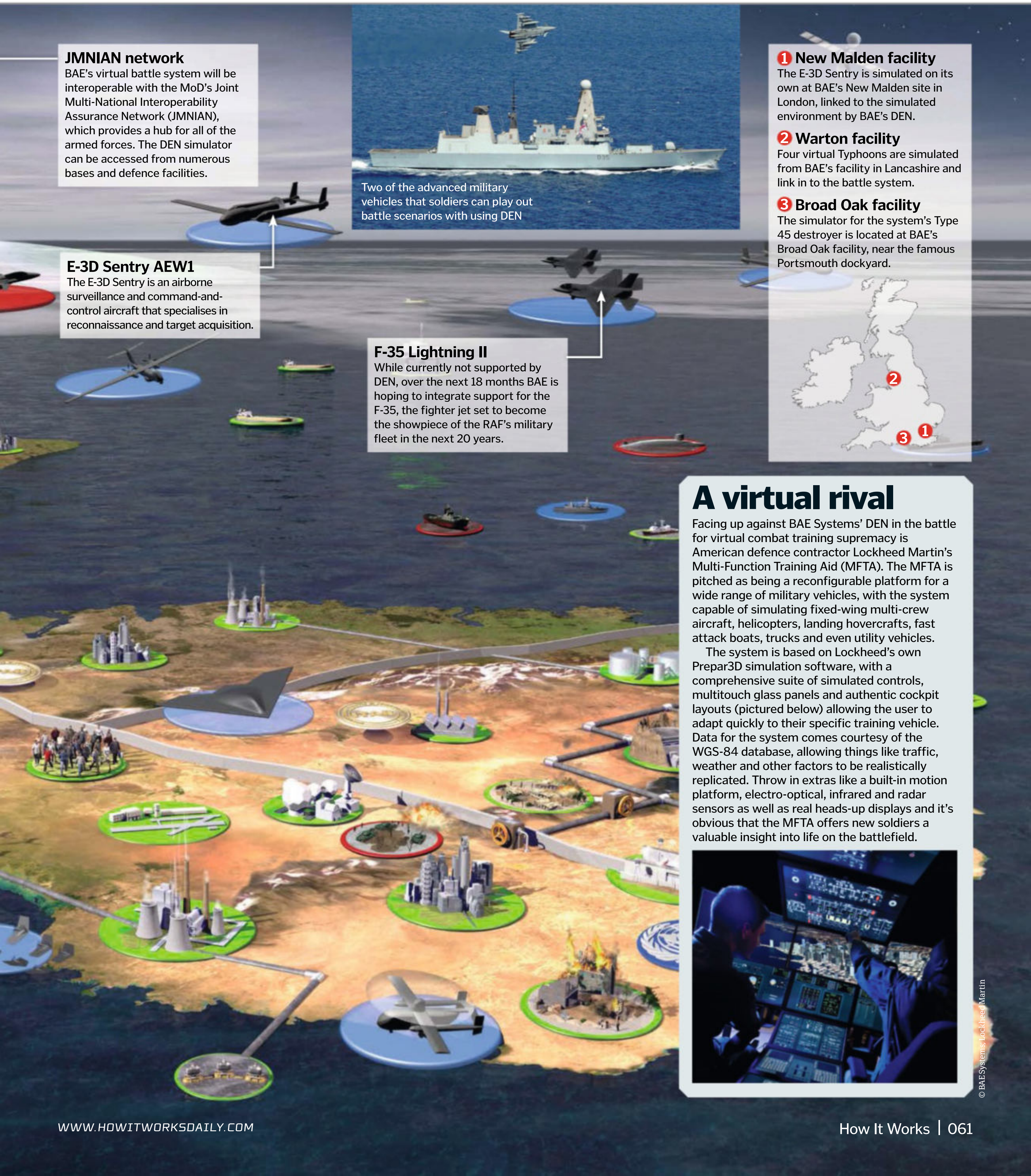
SCAN THE QR CODE FOR A QUICK LINK

BAE's virtual battle team explains the new tech

www.howitworksdaily.com



DID YOU KNOW? *The trial DEN demonstration was the first of its kind in Europe and linked four sites across the UK*



JMNIAN network
BAE's virtual battle system will be interoperable with the MoD's Joint Multi-National Interoperability Assurance Network (JMNIAN), which provides a hub for all of the armed forces. The DEN simulator can be accessed from numerous bases and defence facilities.

Two of the advanced military vehicles that soldiers can play out battle scenarios with using DEN

E-3D Sentry AEW1
The E-3D Sentry is an airborne surveillance and command-and-control aircraft that specialises in reconnaissance and target acquisition.

F-35 Lightning II
While currently not supported by DEN, over the next 18 months BAE is hoping to integrate support for the F-35, the fighter jet set to become the showpiece of the RAF's military fleet in the next 20 years.

1 New Malden facility
The E-3D Sentry is simulated on its own at BAE's New Malden site in London, linked to the simulated environment by BAE's DEN.

2 Warton facility
Four virtual Typhoons are simulated from BAE's facility in Lancashire and link in to the battle system.

3 Broad Oak facility
The simulator for the system's Type 45 destroyer is located at BAE's Broad Oak facility, near the famous Portsmouth dockyard.

A virtual rival

Facing up against BAE Systems' DEN in the battle for virtual combat training supremacy is American defence contractor Lockheed Martin's Multi-Function Training Aid (MFTA). The MFTA is pitched as being a reconfigurable platform for a wide range of military vehicles, with the system capable of simulating fixed-wing multi-crew aircraft, helicopters, landing hovercrafts, fast attack boats, trucks and even utility vehicles.

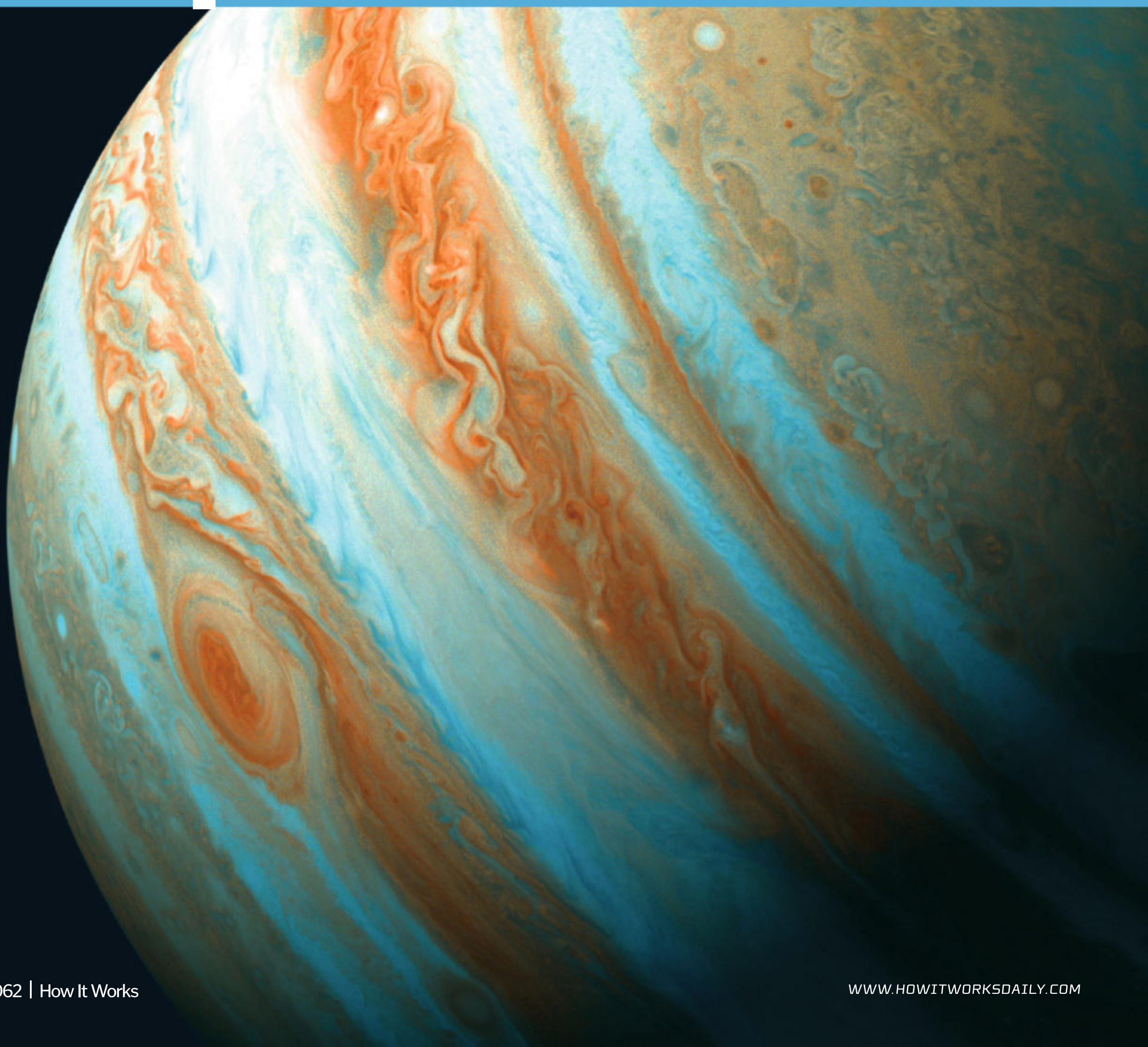
The system is based on Lockheed's own Prepar3D simulation software, with a comprehensive suite of simulated controls, multitouch glass panels and authentic cockpit layouts (pictured below) allowing the user to adapt quickly to their specific training vehicle. Data for the system comes courtesy of the WGS-84 database, allowing things like traffic, weather and other factors to be realistically replicated. Throw in extras like a built-in motion platform, electro-optical, infrared and radar sensors as well as real heads-up displays and it's obvious that the MFTA offers new soldiers a valuable insight into life on the battlefield.

Wildest weather in space

We complain about the weather here on Earth, but weather on other planets is on a whole other scale

Weather on Earth can be extreme, but whatever's happening outside right now where you are, it's a safe bet that it's better than the weather in the rest of the Solar System.

Earth has the nicest weather thanks to a number of features: its size, its distance from the Sun, its axial tilt, orbital and rotational period, and its chemical composition. Although Earth's



RECORD BREAKERS
STORMY SATURN

2,000km

LARGEST STORM ON SATURN

In April 2013, the Cassini spacecraft imaged a storm on Saturn unlike anything seen before. At 2,000km (1,240mi) across, it could cover the UK over 12 times and had winds up to 530km/h (330mph).

DID YOU KNOW? *In 1989, geomagnetic storms caused an electrical blackout in Québec, Canada, that lasted 12 hours*

meteorology can be devastating, in comparison to some of our planetary neighbours, it's actually rather mild. Plus, a lot of our weather can be summed up in one word: water (albeit in various forms). Meanwhile, on planets lacking water, an atmosphere or a magnetic field to shield them from the worst of the Sun's radiation, you have to wonder why we're so keen to visit any of them!

One factor all of the planets have in common is the Sun and its emissions. The heliosphere is considered a part of the Sun's atmosphere, but it extends beyond Pluto, about 19 billion kilometres (12 billion miles) from the star.

So Earth does have some weather in common with other planets. In February 2014, researchers at NASA's Goddard Space Flight Center discovered a phenomenon that is common and rather pedestrian on Earth has much greater repercussions on Venus. A type of solar wind called a hot flow anomaly (HFA) causes massive explosions of energy, but on Earth it's deflected by the magnetosphere. However, Venus has no magnetosphere, so the explosions can cover the entire planet. Not that it was particularly hospitable anyway.

That's not even the strangest weather in the Solar System. While studying it can be difficult, our history of flybys, missions and probes are helping us to create detailed models of climate on other planets like Mars. Learning about similar effects on other planets – even in their more extreme form – is helping us better predict and prepare for changes in weather on Earth.

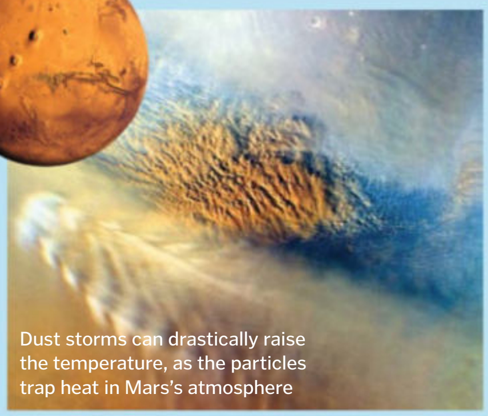
Jupiter's Great Red Spot

One of the defining features of the Solar System's biggest planet is a storm located about 22 degrees south of the equator in the South Equatorial Belt (SEB), commonly known as the Great Red Spot (GRS). Astoundingly, the GRS has been raging for more than 400 years, and is located at a higher altitude and measures colder than the surrounding cloud layer. It rotates anticlockwise, making one full rotation every six Earth days and is currently as large as two Earths across. The storm has shrunk by half its size in the past 100 years – at one point its diameter was measured at more than 40,000 kilometres (24,855 miles).

The GRS is different from storms on Earth because the heat generated within the planet continually replenishes it. Hurricanes on Earth dissipate when they make landfall, but Jupiter is gaseous, so the storm rages on. Jupiter's atmosphere is composed of cloud belts that rotate due to a system of jet streams. The northern side of the storm is bordered by an eastward jet stream and the southern side by a westward jet stream. These hold the storm in place as it makes laps around the planet.

Despite the high winds around it, there's little wind inside the storm. Its colour is probably caused by sulphuric compounds and varies from white to dark red, and sometimes it isn't visible at all. These colour changes seem to correspond to colour changes in the SEB, but without any predictable schedule.

Has lasted over 4,700x longer than Earth's longest storm



Dust storms can drastically raise the temperature, as the particles trap heat in Mars's atmosphere

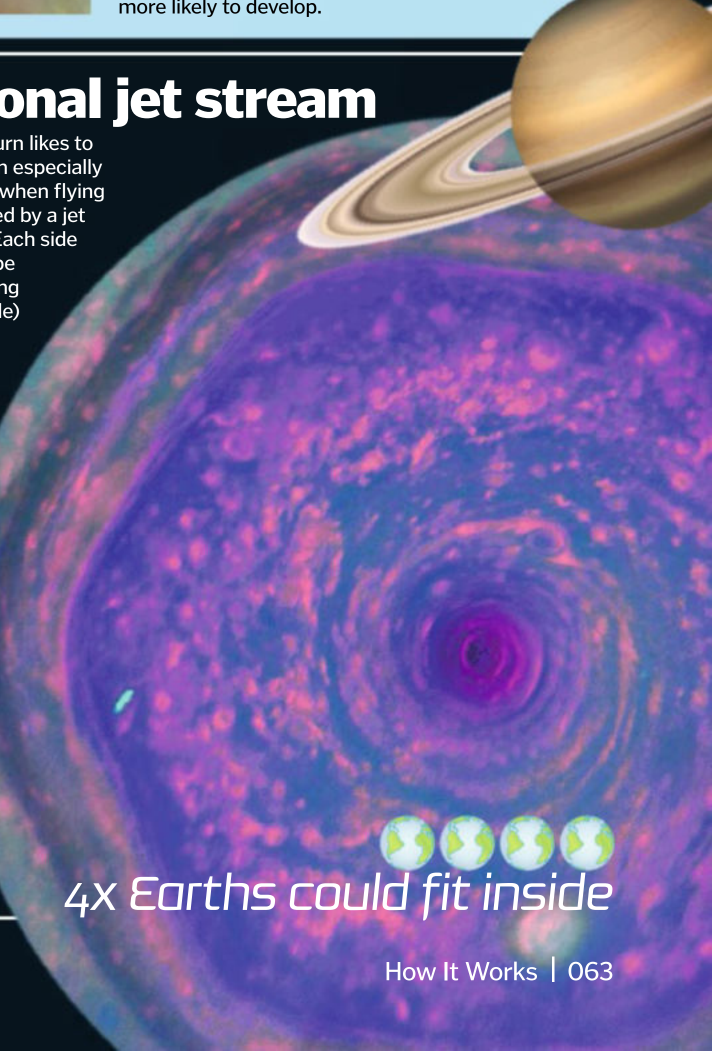
Dust storms on Mars

Earth's deserts have nothing on the Martian landscape when it comes to dust storms. The Red Planet is so dry, dusty and rocky that its dust storms can last for weeks. These storms develop quickly and can cover vast regions of the planet. Because the Martian atmosphere is so thin, superfine particles of dust rise in the air as heat from the Sun warms the atmosphere. Mars has such an eccentric orbit that its seasons are extreme; temperatures can be as low as -143 degrees Celsius (-225.4 degrees Fahrenheit) and as high as 35 degrees Celsius (95 degrees Fahrenheit). During Martian summers, when the temperature swings the most at the equator, dust storms are more likely to develop.

Saturn's hexagonal jet stream

Jet streams are generally circular, but Saturn likes to be different. The Voyager mission made an especially interesting discovery in the early-Eighties when flying over the planet's north pole. It's surrounded by a jet stream that's not circular but hexagonal. Each side of this immense hexagon is estimated to be around 15,000 kilometres (9,321 miles) long and it has a 30,000-kilometre (18,640-mile) diameter. It surrounds a vortex and rotates at the same rate as Saturn (a day on Saturn is about ten and a half hours).

In order to explain this unusual feature, University of Oxford physicists re-created it in a laboratory. They used a cylinder of water to serve as the planet's atmosphere with a ring inside it to represent the jet stream (with green dye to make it visible). The cylinder was placed on a spinning table and the ring spun faster than the water. The faster the ring spun, the less circular the jet stream became. By varying the speed and the differences between the rotations of the water and the ring, different shapes appeared. So the theory is that the rate at which this particular jet stream spins in relation to the Saturnian atmosphere is what leads to the odd hexagonal cloud formation.



4x Earths could fit inside

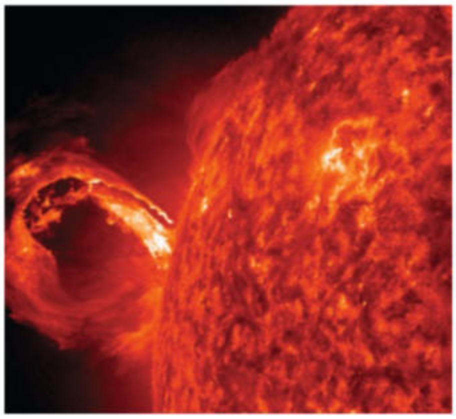
"Neptune is home to the strongest gales anywhere in the Solar System"

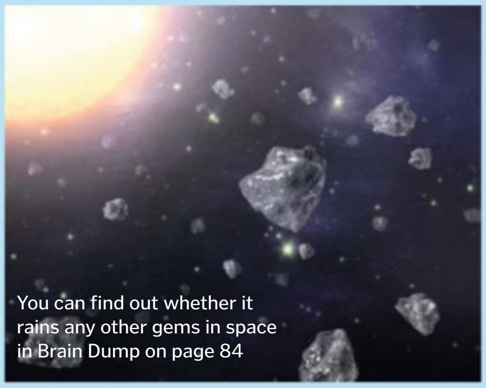
What role does the Sun play in space weather?

There are numerous factors that affect weather on each planet in the Solar System, but they all have one thing in common: the Sun. Two main types of solar activity take place in the Sun's atmosphere that have far-reaching effects. Coronal mass ejections (CMEs) and solar flares can wreak havoc on a planet. CMEs are bursts of magnetic fields and solar winds that release matter and electromagnetic radiation. Solar flares are massive bursts of light and energy that release atoms, ions, electrons and radiation. A CME usually follows a solar flare.

These energy surges from the Sun can result in solar energetic particles (SEPs), highly energised particles including electrons, ions and protons that can travel as fast as 80 per cent the speed of light. SEPs and other matter and radiation that reach Earth cause geomagnetic storms that can have a variety of effects.

They cause the stunning polar auroras, but other effects are less desirable. In the case of solar flares, there's an increase in the amount of UV radiation in the Earth's atmosphere, which can affect the movement and longevity of satellites by making the atmosphere denser. They can cause interference and disruption of communications and navigation on the surface, while particles from flares can damage delicate electronics on satellites or the International Space Station. They can even cause changes in the Earth's climate.





You can find out whether it rains any other gems in space in Brain Dump on page 84

Saturn's diamond rain

Some researchers believe that lightning storms on Saturn could result in diamond precipitation – as much as 1,000 tons each year. The theory is that lightning zapping the methane in the atmosphere releases carbon atoms from the gas. These carbon atoms stick together and drift down towards the planet's core. As the pressure and temperature mount, the carbon is compressed into graphite and eventually diamonds that could be as big as a centimetre (0.4 inches) in diameter.

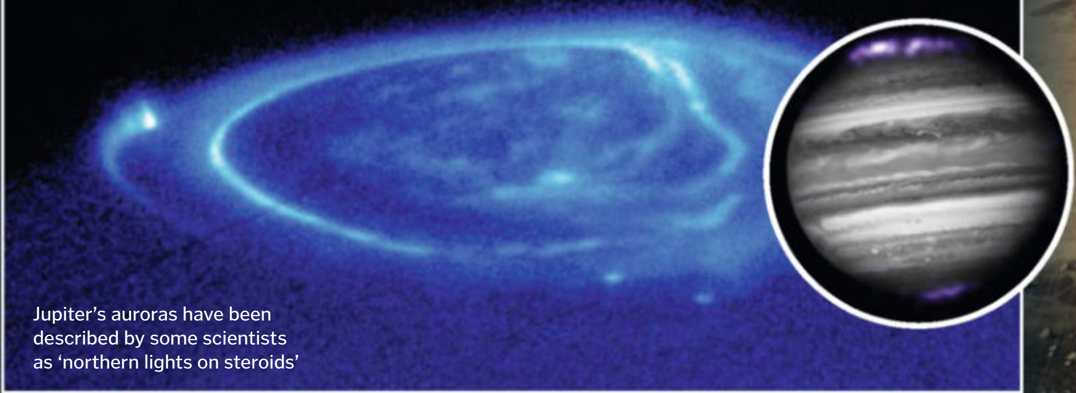
However, when the diamonds reach the core – where temperatures can be as hot as 7,727 degrees Celsius (13,940 degrees Fahrenheit) – the gemstones would melt into a liquid state.

Violent Neptunian winds

The outermost planet in our Solar System has some seriously extreme weather in general, but what really blows astronomers away is its wind. In fact, Neptune is home to the strongest gales anywhere in the Solar System, topping out at over 2,100 kilometres (1,300 miles) per hour – about the speed of a fighter jet. By comparison, winds on Earth generally max out at 400 kilometres (250 miles) per hour. These powerful winds move in a direction opposite from the rotation of the planet. There are two different theories for what causes these winds. One idea is that although they're very powerful, these winds remain high up in the atmosphere, in a layer no more than 1,000 kilometres (600 miles) thick. This means that the processes causing these winds are also shallow, likely due to the condensation and evaporation of moisture in the atmosphere. The other theory is that these processes are much lower in the atmosphere, caused by the meeting of the heat generated from within the planet as its core shrinks as it meets the extreme cold at the surface (below -200 degrees Celsius/-328 degrees Fahrenheit). If the winds do prevail deeper into the atmosphere, they may also be so intense because the planet's featureless surface contains nothing to slow them down.

Jupiter's electric auroras

The auroras on Earth get a lot of attention for their beauty, but Jupiter has auroras larger than the entire Earth. In fact, they produce nearly a million megawatts of energy! And unlike Earth-based auroras, they're always happening. On Earth, the light displays are caused by solar storms, but Jupiter's auroras are self-generated. As the planet rotates, it generates electricity at its poles and forces charged particles (ions) into the atmosphere, which causes a reaction that results in beautiful light displays. One potential source for the ions is Jupiter's moon Io, but scientists aren't quite sure how this happens. Ultraviolet images of the auroras reveal not just their blue glow, but also three blobs of light. These are Galilean moons Io, Ganymede and Europa as they interact with Jupiter's magnetic field.



Jupiter's auroras have been described by some scientists as 'northern lights on steroids'

What would happen if you stood on Venus and it rained?

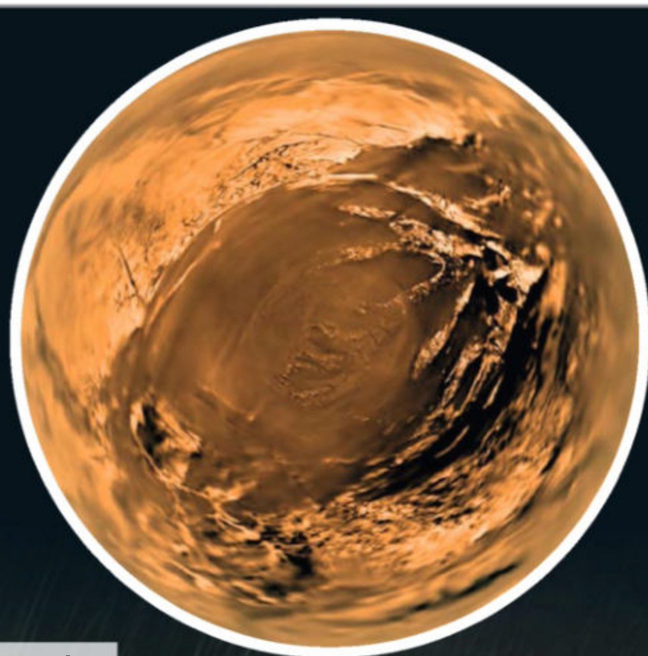
A You'd melt **B** You'd smell funny **C** Nothing

Answer:
Although rain on Venus is corrosive sulphuric acid, the surface heat is so intense (480°C/900°F) that the rain evaporates before reaching it. Of course, acid would be the last of your worries with that intense heat and a surface pressure 90 times greater than Earth's!

DID YOU KNOW? *Solar flares can release energy equivalent to the explosion of millions of 100-megaton hydrogen bombs*

Titan is home to methane rain

Titan looks Earth-like thanks to its abundance of lakes, rivers and clouds. But appearances can be deceiving; instead of a water cycle, Saturn's largest satellite has a methane cycle. Seasonal rains fill the moon's basins, the contents of which evaporate and condense into clouds that once again release rain.



Titan's methane cycle in focus

Titan has a methane/ethane cycle that follows the seasons, similar to the monsoon rains in some places on Earth

Top 5 weather satellites

GPM – Launch: 2014

The Global Precipitation Measurement will provide 4D views of hurricanes, rainstorms and even falling snow on Earth. It will be used for both long-term climate research and provide live weather forecasts.

DSCOVR – Launch: 2015

The Deep Space Climate Observatory satellite will spot space weather (like solar flares) that could be damaging to Earth. DSCOVR will be in an orbit 1.5mn km (932,000mi) away to escape some of the Earth's magnetic effects.

SOHO – Launch: 1995

The Solar and Heliospheric Observatory mission is in a halo orbit around the Earth. SOHO was commissioned to study the Sun, but it has also discovered more than 2,000 comets.

CASSIOPE – Launch: 2013

The Cascade Smallsat and Ionospheric Polar Explorer is a small satellite specifically designed to gather data on solar storms that affect the Earth's upper atmosphere and cause auroras as well as magnetic interference.

SST – Launch: 2003

The Spitzer Space Telescope observatory is unusual because it has a heliocentric orbit, slowly drifting away from Earth. In its extensive studies of stars, the SST has discovered space weather on some of the smallest stars around, known as brown dwarfs.

> "Normally, once a star reaches the end of its life, it violently expels gas into the void of space"

Not really a giant space insect (so don't worry), the Ant Nebula is possibly shaped this way due to magnetic influences

Exploring the Ant Nebula

Why this fascinating view offers an insight into what our Sun may become

The Ant Nebula is one of the most intriguing phenomena in our galaxy. Around two light years in diameter it is located around 3,000 light years away from our Solar System, in the constellation of Norma.

The nebula is the result of the death of a star similar to our Sun, but what has intrigued astronomers across the globe is the peculiar shape it has taken on. With a bulge either side of the star, the nebula resembles an ant, the two lobes looking like the head and thorax.

Scientists still aren't 100 per cent sure as to how this space insect formed. Normally, once a star reaches the end of its life, it violently expels gas into the void of space. However, the Ant Nebula hasn't managed to entirely let go of its gaseous material. Some theories as to why this unique event has occurred include a second, hidden star orbiting Menzel 3 (the proper name for the Ant Nebula), holding the gas in close proximity. Another theory suggests that the star itself is holding the gas close with its own magnetic field. The rotation of the star causes the magnetic field to fluctuate, but without letting the gas get too far away.

One of the other reasons for keeping a close eye on Menzel 3 is to get an insight of what might happen to our Sun when it starts to die, some 5 billion years from now. Interestingly close examination of the nebula shows a controlled, symmetrical pattern of flowing gas – very different from the chaotic swirls that scientists would expect to see.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"Nereid reflects only 14 per cent of light that it receives so human observation is problematic"

Neptune's boomerang moon

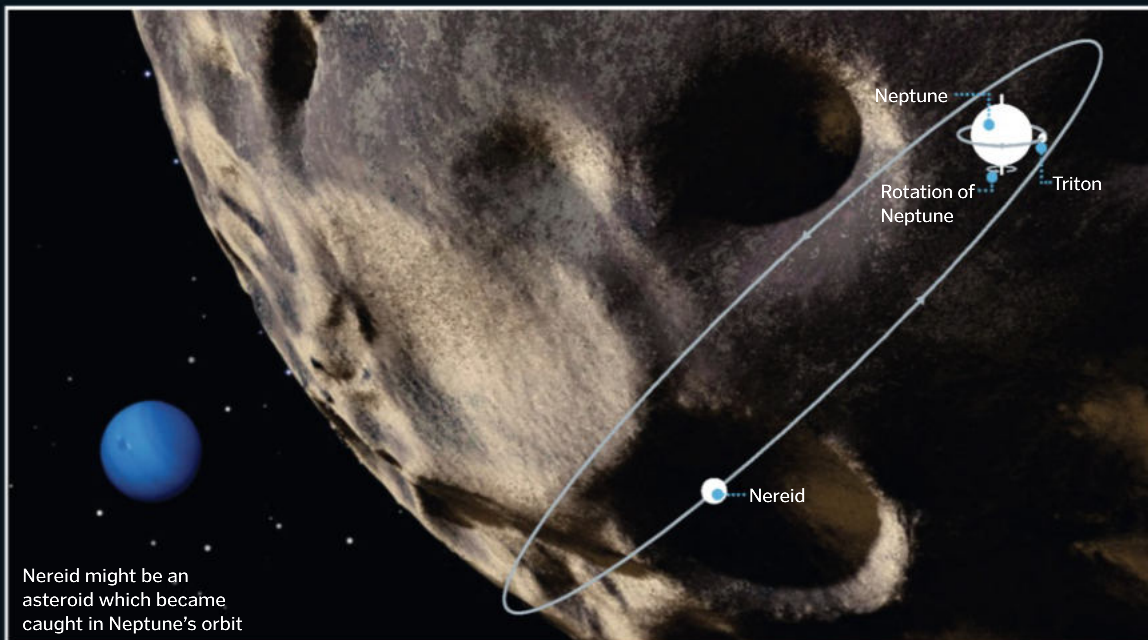
Meet the natural satellite with the most eccentric orbit of any moon in the Solar System

Nereid is Neptune's third-largest moon behind Triton and Proteus. It has a diameter of approximately 340 kilometres (210 miles) and its most interesting characteristic is that it has the most fluctuating orbit of any moon in the Solar System.

The second of the planet's moons to be discovered, its orbit is so changeable it can vary from 9.65 million kilometres (6 million miles) away from the planet to just 1.37 million kilometres (854,000 miles) at its closest.

Astronomers are divided when it comes to the reason for its eccentric trajectory but one school of thought is that the satellite was captured from the Kuiper asteroid belt in the outer Solar System, which explains its unusual orbit.

Further, Nereid, which has a surface composed primarily of ice and silicon, reflects only 14 per cent of light that it receives so human observation is problematic. It is so faint that Voyager 2 could only take a low-resolution image of it when it passed in 1989.



Nereid might be an asteroid which became caught in Neptune's orbit

Three of Neptune's less wayward moons

Triton

The first to be discovered and by far the largest, Triton is the king of Neptune's moons. Bigger than Pluto, it orbits the planet in a retrograde motion, which is the opposite direction to Neptune. It is made of rock and ice.

Proteus

The second largest, Proteus also has the farthest orbit of any of Neptune's six inner moons. Proteus is significantly smaller than Triton, with its diameter being a measly 440km (273mi) compared to Triton's 2,707km (1,681mi).

S/2004 N 1

New moons are still being spotted. The biggest cluster was during Voyager's visit in 1989 when almost half of the moons were found. The latest satellite – s/2004 N 1 – was only discovered in July 2013 by the Hubble Space Telescope.


Space dust may have been what originally brought water to Earth

Space dust secrets

How could the remnants of our galaxy's formation be a possible source of water?

As small in scale as it may be, space dust – also called interplanetary dust particles (IDPs) – forms a large part of the matter in our Solar System. Mainly originating from the Asteroid Belt between Mars and Jupiter, these tiny particles are comprised of debris from comets, meteorites and asteroids.

Less than a few millimetres in size, they can even offer an insight into how the Milky Way was formed by studying their physical features and trajectory. Moreover, scientists claim that IDPs could have been responsible for delivering water to Earth and other possibly habitable planets like Mars. Space dust is constantly eroded by hydrogen in solar wind that reacts with oxygen present in the dust. This creates amorphous rims, which can contain water.

"The lander will then launch a harpoon to anchor itself in place and drill into the comet"

Chasing comets

Awakened from its three-year nap, the Rosetta orbiter is primed to make history by releasing a lander onto a comet

The Rosetta Stone, discovered in 1799, allowed scholars to decipher ancient hieroglyphics and uncover secrets of the past. The Rosetta orbiter is aiming to do much the same thing in outer space.

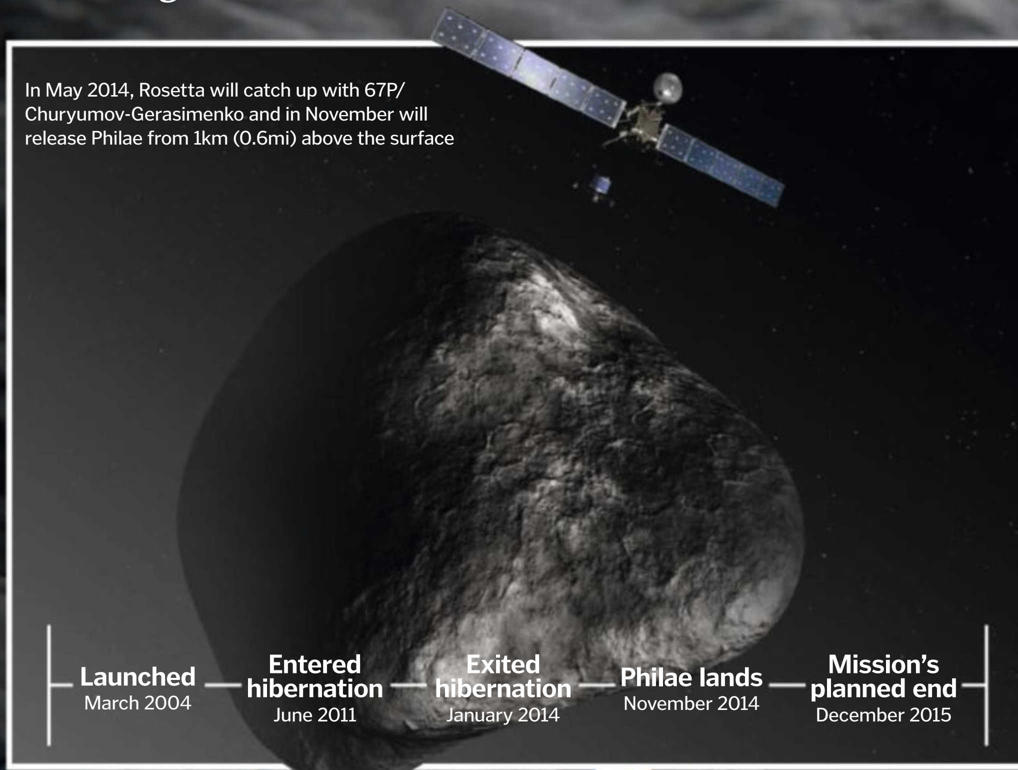
A joint venture between 14 European countries and the United States, the Rosetta mission is aiming to become the first probe to orbit and place a lander (named Philae) on a comet. From there, scientists hope to glean valuable information about the composition of these icy rocks and better understand how the Solar System formed. As comets are the least altered remnants from the early days of our planetary system, they are our best chance of understanding what conditions were present when our Sun was initially developing.

A further mission objective is to ascertain whether comets were responsible for seeding life on Earth. The composition of carbon, hydrogen, oxygen and nitrogen present in organic molecules in a comet are strikingly similar to the building blocks of life on our world, so the Rosetta mission should shed more light on this issue. It will do this by analysing the molecules more closely than ever before with the cutting-edge spectrometers and analysis tools on board Philae.

Rosetta's destination, 67P/Churyumov-Gerasimenko, is a four-kilometre (2.5-mile) diameter comet, currently orbiting the Sun between Mars and Jupiter. The culmination of a ten-year mission, in which the 3,000-kilogram (6,614-pound) spacecraft was asleep for three years while too far away from the Sun for its solar panels to generate enough power for all its functions, will come in November 2014 when Philae will be released and land at less than walking pace upon the surface.

The lander will then launch a harpoon to anchor itself in place and drill into the comet before collecting samples and returning data to scientists back on Earth.

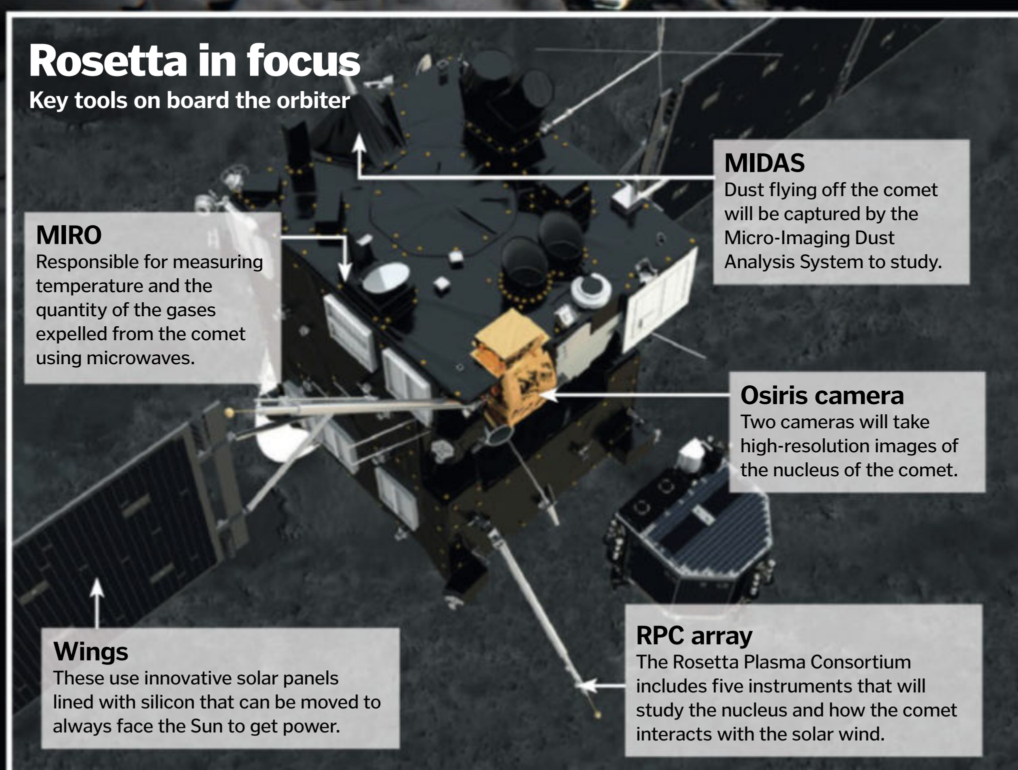
This is one of the most ambitious comet-based projects ever undertaken. The successful launch and re-awakening is complete, but now the team at ESA have an anxious eight-month wait before the craft drops its valuable payload.



In May 2014, Rosetta will catch up with 67P/Churyumov-Gerasimenko and in November will release Philae from 1km (0.6mi) above the surface

Rosetta in focus

Key tools on board the orbiter



THE STATS
ROSETTA SPECS

LAUNCHED **2004**

100kg LANDER WEIGHT

2,900kg TOTAL ORBITER WEIGHT

1,670kg PROPELLANT

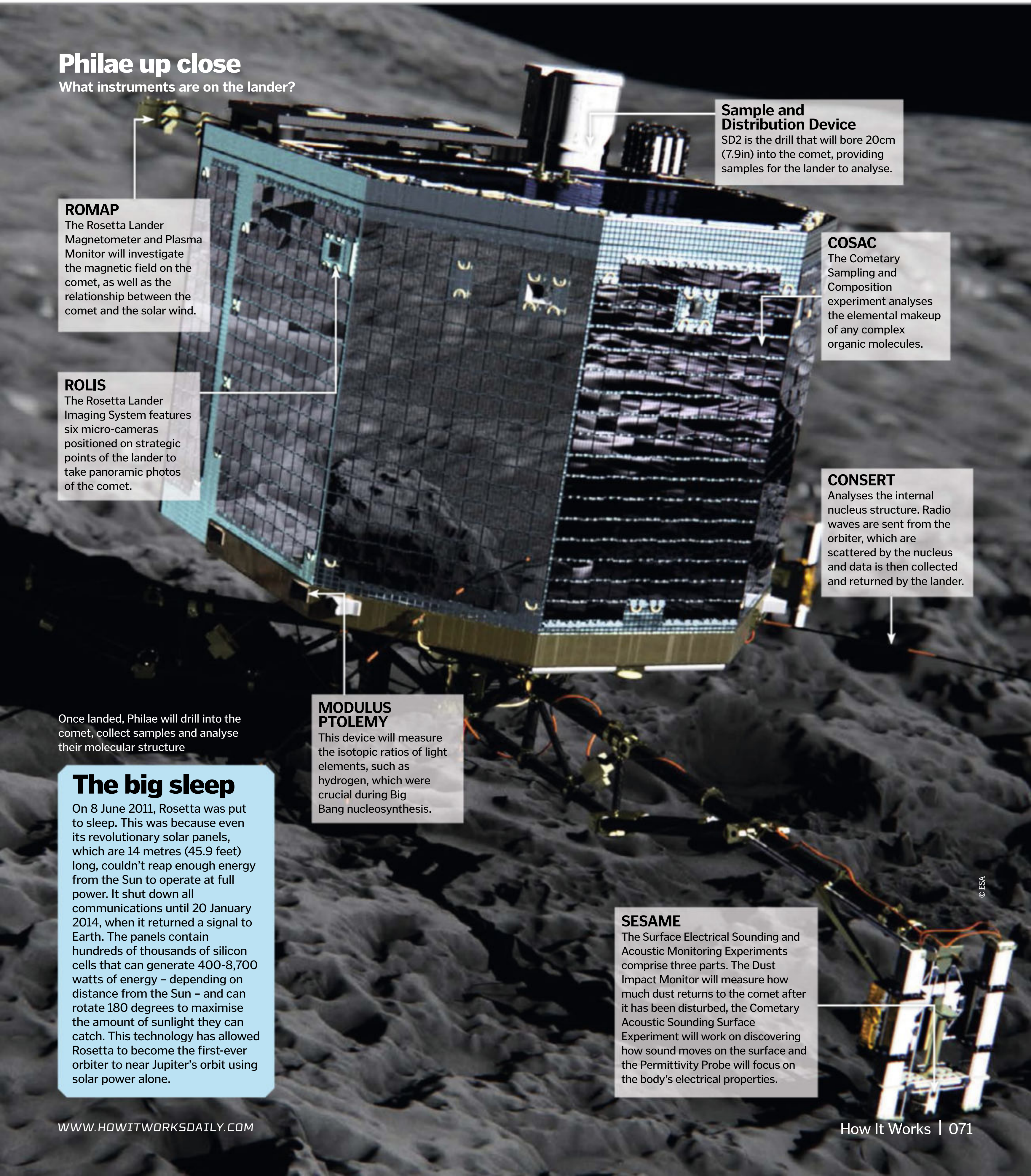
64m² SOLAR PANEL AREA

32m WING SPAN

DID YOU KNOW? *Rosetta has circled the Sun five times, getting three gravitational boosts from Earth and one from Mars*

Philae up close

What instruments are on the lander?



Sample and Distribution Device
SD2 is the drill that will bore 20cm (7.9in) into the comet, providing samples for the lander to analyse.

ROMAP
The Rosetta Lander Magnetometer and Plasma Monitor will investigate the magnetic field on the comet, as well as the relationship between the comet and the solar wind.

COSAC
The Cometary Sampling and Composition experiment analyses the elemental makeup of any complex organic molecules.

ROLIS
The Rosetta Lander Imaging System features six micro-cameras positioned on strategic points of the lander to take panoramic photos of the comet.

CONSERT
Analyses the internal nucleus structure. Radio waves are sent from the orbiter, which are scattered by the nucleus and data is then collected and returned by the lander.

MODULUS PTOLEMY
This device will measure the isotopic ratios of light elements, such as hydrogen, which were crucial during Big Bang nucleosynthesis.

Once landed, Philae will drill into the comet, collect samples and analyse their molecular structure

SESAME
The Surface Electrical Sounding and Acoustic Monitoring Experiments comprise three parts. The Dust Impact Monitor will measure how much dust returns to the comet after it has been disturbed, the Cometary Acoustic Sounding Surface Experiment will work on discovering how sound moves on the surface and the Permittivity Probe will focus on the body's electrical properties.

The big sleep

On 8 June 2011, Rosetta was put to sleep. This was because even its revolutionary solar panels, which are 14 metres (45.9 feet) long, couldn't reap enough energy from the Sun to operate at full power. It shut down all communications until 20 January 2014, when it returned a signal to Earth. The panels contain hundreds of thousands of silicon cells that can generate 400-8,700 watts of energy – depending on distance from the Sun – and can rotate 180 degrees to maximise the amount of sunlight they can catch. This technology has allowed Rosetta to become the first-ever orbiter to near Jupiter's orbit using solar power alone.

Life in the trenches

100 years on, why has trench warfare come to define WWI?

World War I represented a major shift in warfare practice. Aircraft and machine guns were two examples, but what truly dictated this conflict was trench warfare.

The first trenches of note were dug by Germans in September 1914 after their charge through France was halted by Allied forces. In order to avoid losing ground, they dug in, creating deep crevasses to hide in. The Allies quickly realised they couldn't breach these defences and followed suit. What ensued was a race to outflank the opponent along northern France. The first trenches were fairly shallow ditches, but evolved into an elaborate system of frontline trenches, support trenches and barbed wire fences.

It would take 450 men six hours to construct a trench of just 250 metres (820 feet), after which sandbags, wooden walkway planks and barbed wire needed to be strategically placed to stop flooding, collapsing and enemy advances. They were dug in zigzag patterns to stop enemies taking out an entire group of soldiers in one attack. The most time-effective method of trench digging was standing on the ground and digging downward, but that left soldiers at the mercy of enemy fire. The alternative was to dig down then along, while still in the hole. This was safer but much slower. ▶

WWI battlefield revealed

See how the complex trench system was laid out

KEY DATES

WWI MILESTONES

Sept 1914
Allied resistance at Marne forces the advancing German army to dig trenches.

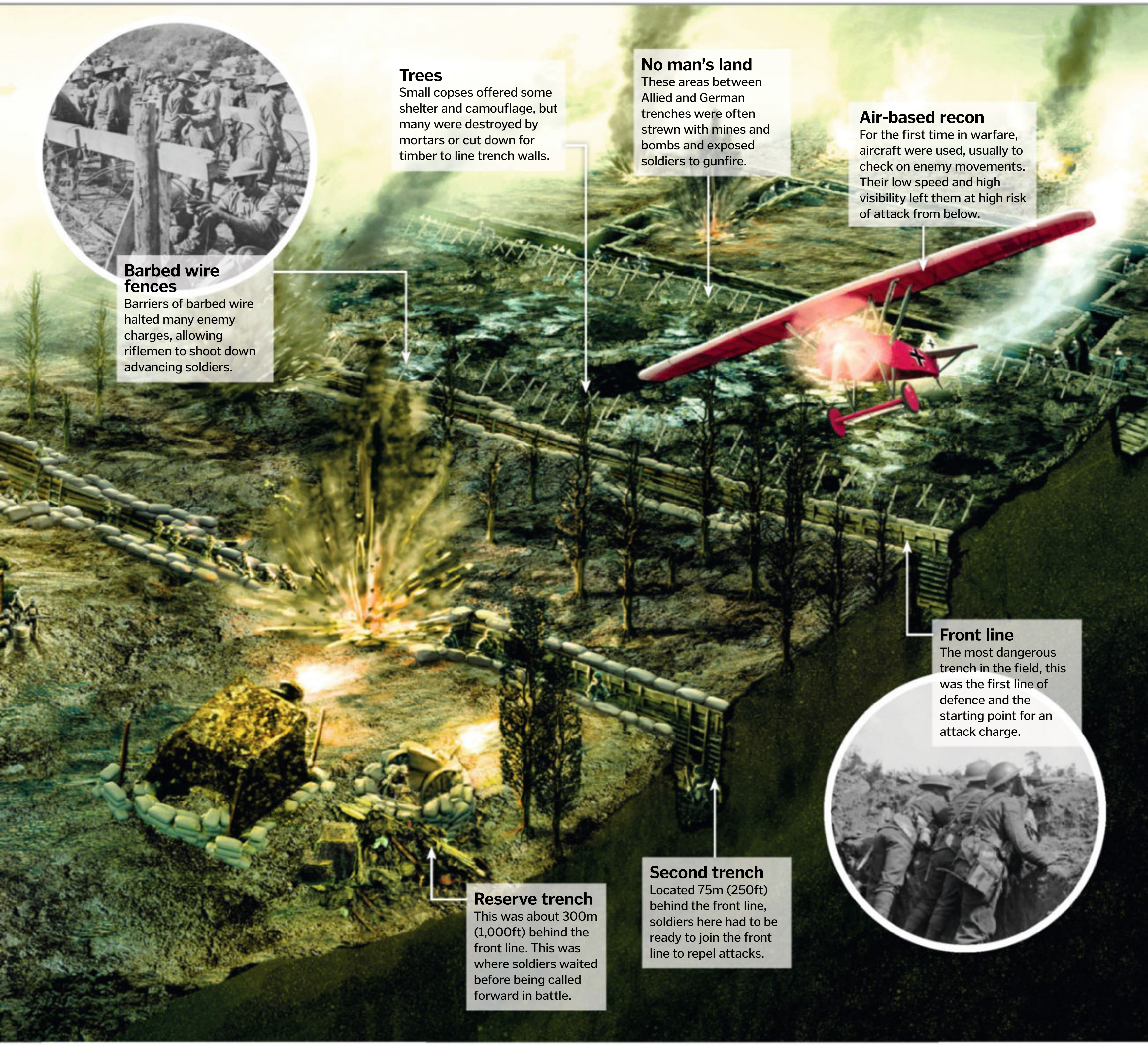
Nov 1914
The first Battle of Ypres in Flanders draws to a close, resulting in a victory for the Allies.

Jul 1916
The devastating Battle of the Somme results in heavy casualties on both sides.

Apr 1917
British and Canadian forces take Vimy Ridge near the town of Arras in northern France.

Oct 1918
Allies break through the so-called Hindenburg Line, gaining a war-ending victory.

DID YOU KNOW? *Around 140,000 Chinese labourers fought in Allied trenches during World War I*



"The German trenches were so well fortified that the British shells barely made an impact"

Located in north-east France, Marne was the site of the war's first example of trench warfare. German and Allied forces both realised the defensive power of this strategy so engaged in a shovelling 'Race to the Sea', building trenches all the way to the North Sea at Ypres, Belgium.

This then became the location for a bed-in that lasted for the remainder of the war, with attacks and counterattacks barely gaining any ground at all, but at the cost of millions of lives.

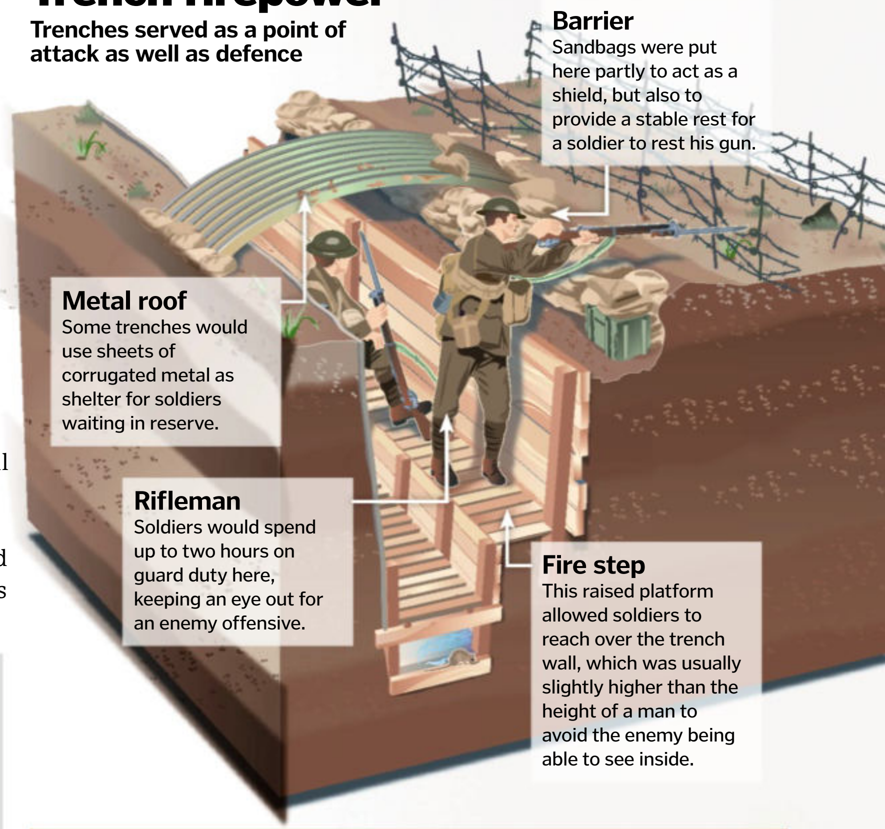
Verdun was another bloody site, with the Germans launching a devastating attack on the fortified town. They broke French resistance but the counter-offensive eventually drove them back to their starting point, resulting in a similarly prolonged trench standoff.

The German forces failed to conquer Verdun because they had to focus on the British army's assault on the Somme. This began with a massive week-long bombardment followed by an infantry attack. However, the German trenches were so well fortified that the British shells barely made an impact, so thousands of Allied troops fell victim to the ruthless German machine guns.

The end came at St Quentin Canal in France. The British managed to storm through the Hindenburg Line, forcing the Germans back and bringing about the first discussions of surrender.

Trench firepower

Trenches served as a point of attack as well as defence



Job roles in the trenches

The majority of soldiers in the trenches were there to directly engage in combat. These soldiers would have a spectacular range of abilities and experiences. Some may have been grizzled war veterans, while others would be fresh recruits, straight out of training. These people would be responsible for day-to-day maintenance, guarding and, eventually, going over the top and launching an offensive on the German trenches.

Officers 1 would also be stationed in the trench. They would be soldiers of higher status and would be in charge of organising and leading night patrols, which tried to keep track of the enemy's location. They had marginally more luxury than the other soldiers, sleeping in a proper dugout in the trench and having first pick of the food.

Medics 2 were stationed in three positions: the collecting zone (right by the battlefield), the evacuating zone (between the front and rear trenches) and the distributing zone (where they would treat the wounded in pop-up hospitals). If a soldier couldn't be moved, they would be treated where they lay. The Royal Army Medical Corps (RAMC) is the only part of the British army in which two members hold double Victoria Crosses.

Listeners 3 would move through tunnels closer to the enemy's front line than the trenches. The idea was to try to hear enemy plans and put a halt to the enemy planting mines close to their trench. This was a very dangerous role as tunnels could collapse at any time.


1


2


3

A day on the front line

Soldiers in the British army would spend about 15 per cent of their active service on the front line and 40 per cent in the reserve trenches.

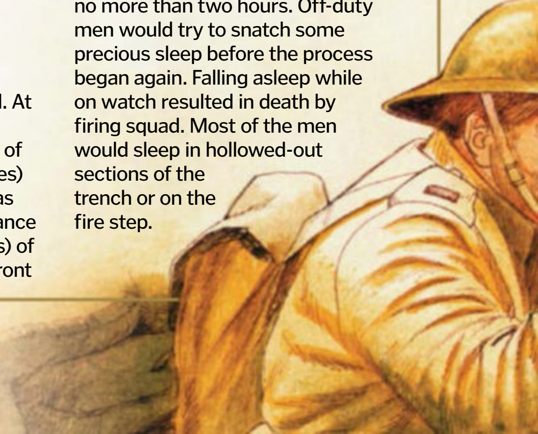
The average day on the front line would begin with a stand to. This would be around an hour before sunrise and involved all soldiers standing on the fire step, rifles ready and bayonets fixed. They would then begin the 'morning hate', firing their guns into the morning mist. This had the dual benefit of relieving tension and frustration, as well as helping to deter a possible dawn raid.

Breakfast would then be served, consisting of biscuits or bread and canned or salted meat. Following breakfast would be a period of chores. These could range from cleaning weapons and fetching rations to guard duty and trench maintenance. The latter would often involve repairing shell damage or trying to shore up the damp, underfoot conditions.

One of the main challenges in everyday trench life was the food. At the start of the war, each soldier received 283 grams (ten ounces) of meat and 227 grams (eight ounces) of vegetables per day. However, as the war wore on, the meat allowance reduced to 170 grams (six ounces) of meat and, if you weren't on the front line, you only got meat on nine out of 30 days. Diets were bulked out with corned beef, biscuits and bread made of dried ground turnips. As the kitchens were so far behind the front line, it was nearly impossible to provide hot food to the troops at the front, unless the men pooled their resources and bought a primus stove to heat their food and make tea. Other common meals included pea soup with horse meat and Maconochie, a weak soup containing sliced carrots and turnips.

As dusk fell, the soldiers would engage in an evening version of the morning hate. Essential tasks like repairing barbed wire and rotation of troops were done after dark, as the enemy was less likely to be able to launch an effective attack.

Guards would look out for night-time raids, with watches lasting no more than two hours. Off-duty men would try to snatch some precious sleep before the process began again. Falling asleep while on watch resulted in death by firing squad. Most of the men would sleep in hollowed-out sections of the trench or on the fire step.



5 TOP FACTS
TRENCHES TODAY

Sanctuary Wood
1 This is a museum and trench network 3.2km (2mi) east of Ypres. You can visit the woodland where soldiers once sheltered and walk in their footsteps in the trenches.

Yorkshire Trench
2 Originally dug by British troops in 1915, the Yorkshire Trench – located north of Ypres – has been restored in considerable detail and is free for all to visit today.

Vimy Memorial Park
3 Free tours to this site are provided by Canadian students. Canada was granted this piece of land after they were instrumental in taking it from Germany in 1917.

The Somme
4 One of the most significant battle sites in the war, where an estimated 60,000 men died in one day. The area is still covered in craters and trench lines to this day.

Verdun
5 Another key site in the battle for the Western Front, Verdun was the location of a bloody battle, with almost 300,000 soldiers killed over ten months of fighting.

DID YOU KNOW? *The machine gun was originally designed by American inventor Hiram Maxim as long ago as 1884*

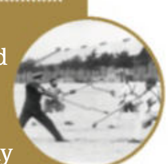
5 key WWI weapons

1 Machine gun
The machine gun was one of the definitive weapons of WWI. At the outbreak of war, Germany had 12,000 machine guns, while the British and French only had a few hundred between them.

2 Tank

Early tanks were based on farming vehicles, the caterpillar tracks allowing for movement over uneven muddy ground. They were slow and unreliable but once these problems were ironed out and they were weaponised, the British enthusiasm for the tank helped them win the war.

3 Rifle
Despite the advance of long-range or automatic weapons like machine guns and mortar shells, the rifle continued to be an essential piece of military kit.

4 Bayonet

These blades affixed to the front of rifles were only useful in close combat. The French army used needle blades, while the German army developed the saw-back bayonet blade.

5 Flame-thrower

By 1915, German soldiers had portable flame-throwers that terrified the British army at Flanders. The British attempted to come up with flame-throwers of their own, but with little success, while the French developed their own self-igniting, lightweight flame-throwers, with more success than the British.

What kind of war did Aztecs fight with their neighbours?

A Honey war **B** Flower war **C** Sugar war

Answer:
A flower war was a ritualistic battle that took place in prearranged locations with limited forces, where the Aztecs took prisoners for sacrifice. These wars had the added benefit of making the Aztecs look stronger and more powerful while limiting fighting and loss of life.

DID YOU KNOW? *Aztecs and Mayans, who both lived in Central America, had extensive contact – most of it peaceful trade*

Aztec warriors

Ready yourself for battle as you learn about the martial side of this Central American civilisation

The Aztecs were a fierce and powerful group of warriors, defined by their religious fervour and class system.

New warriors had to work their way up from the bottom by capturing prisoners. This was an important part of a young warrior's introduction into the martial society, as the Aztecs would sacrifice prisoners to the god Huitzilopochtli. Once a warrior had captured a prisoner, he would attain the rank of a warrior.

Most Aztecs wore padded cotton armour called ichcahuipilli, which remained cool in the intense heat of Mexico but was also tough enough to deflect most arrows and darts. However, the elite fighting forces – called the 'Eagles' and 'Jaguars' – dressed as their namesakes. Eagle warriors donned feathers and an eagle-head helmet (see annotated warrior), while Jaguar fighters were wrapped in the skin of the South American big cat. The higher up the social rank you rose, the more elaborate the costume became.

Their main weapon was the maquahuitl, a wooden sword with vicious shards of obsidian embedded down the sides. This deadly tool was capable of beheading a human. The Aztecs were also proficient users of arrows, slings and the atlatl, a throwing device that allowed them to hurl spears harder and faster than possible with the arm alone.

Although fearsome warriors, Aztec armour and weapons could not compete with Spanish steel

"Despite the massive cost of construction and the popularity of chariot racing, admission was free"

The Circus Maximus

Explore the largest stadium in the history of the Roman world and find out what spectacular events were held there

As the name suggests, the Circus Maximus was Rome's biggest circus, or racetrack. It was established by Tarquinius Priscus, the fifth king of Rome, in the sixth century BCE. The first circus to be erected in the city, the original building was a wholly wooden construction. Increased in size by Julius Caesar, a triple stone arch was later added to honour Emperor Titus, before the entire structure was rebuilt in stone and concrete by Emperor Trajan in 103 CE, after a fire destroyed its wooden predecessor.

Although various monumental additions were continually added during the following centuries, the Circus Maximus essentially remained the same for the next 400 years. Despite the massive cost of the circus's construction and the popularity of chariot racing, admission was entirely free – anyone could attend races, including poorer citizens.

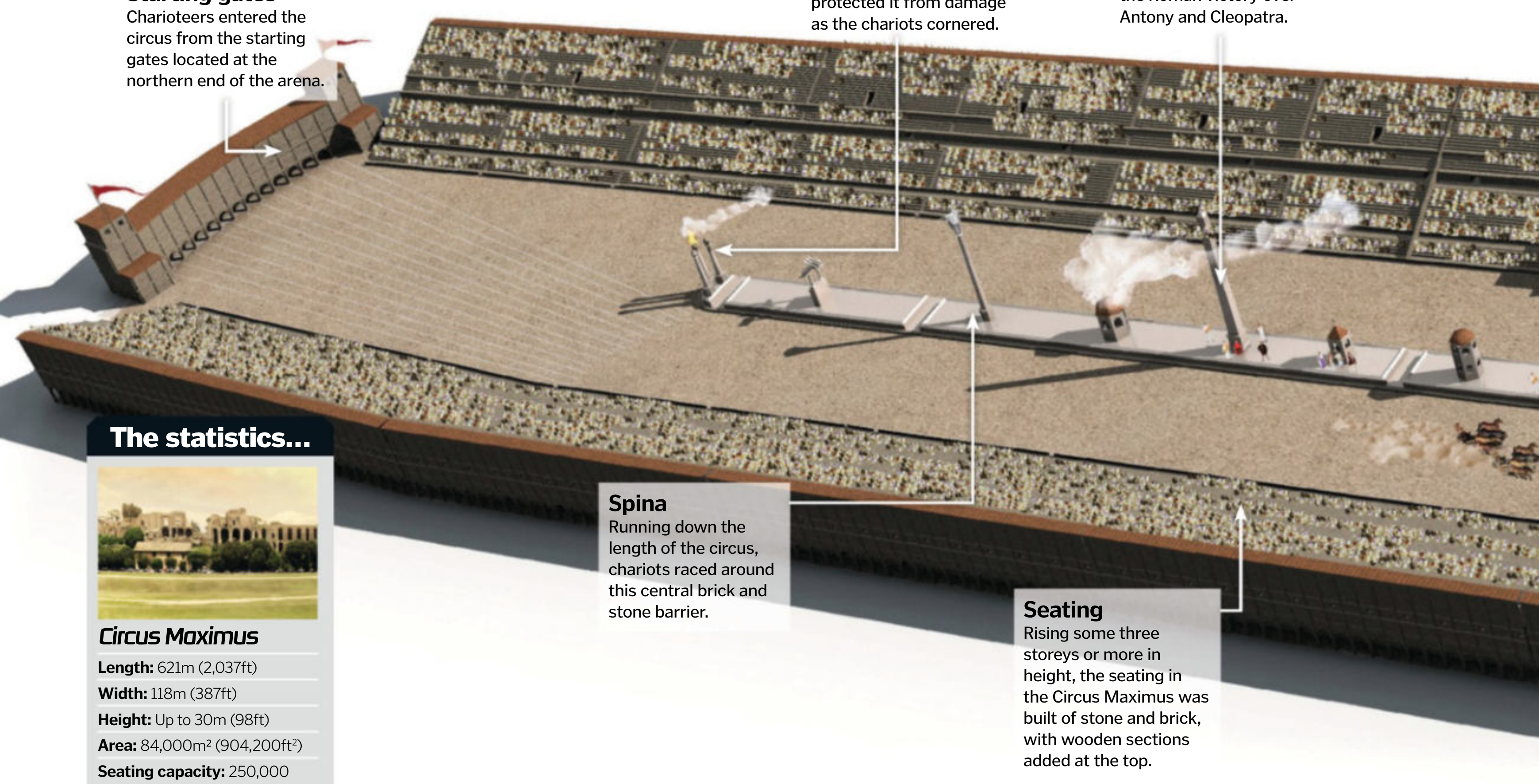
Betting was popular with all classes and under the stands were food stalls, stables and shops that serviced charioteers and public alike. Several small temples and shrines were also incorporated into the complex and religious festivals were held annually within its walls. Other forms of entertainment also featured in the venue's yearly calendar, including musical recitals, athletics competitions, plays and staged animal hunts.

With the advent of Christianity and the crumbling Roman Empire, the fortunes of the Circus Maximus quickly declined. The last recorded chariot race took place in 549 CE, after which Rome's greatest entertainment venue was abandoned and became a quarry.

In 1587, the two Egyptian obelisks that stood on the central spine were removed by Pope Sixtus V to adorn different parts of the city; the rest of the building disappeared soon after. Today, the circus's site is used as a public park and there is little to indicate its former glory.

A trip to the Roman circus

How was the Circus Maximus laid out to enable vast crowds to comfortably enjoy sport and other spectator events?



Starting gates
Charioteers entered the circus from the starting gates located at the northern end of the arena.

Metae
Made from three conical stone pillars, these turning posts marked the ends of the central dividing barrier and protected it from damage as the chariots cornered.

Egyptian obelisk
Removed from Heliopolis in Egypt by Augustus, the obelisk commemorated the Roman victory over Antony and Cleopatra.

Spina
Running down the length of the circus, chariots raced around this central brick and stone barrier.

Seating
Rising some three storeys or more in height, the seating in the Circus Maximus was built of stone and brick, with wooden sections added at the top.

The statistics...

Circus Maximus

Length: 621m (2,037ft)
Width: 118m (387ft)
Height: Up to 30m (98ft)
Area: 84,000m² (904,200ft²)
Seating capacity: 250,000

1. BIG

Stadium of Philippopolis
Built near Plovdiv, Bulgaria, in the second century CE, this stadium is 240m (787ft) long and could host 30,000 people.

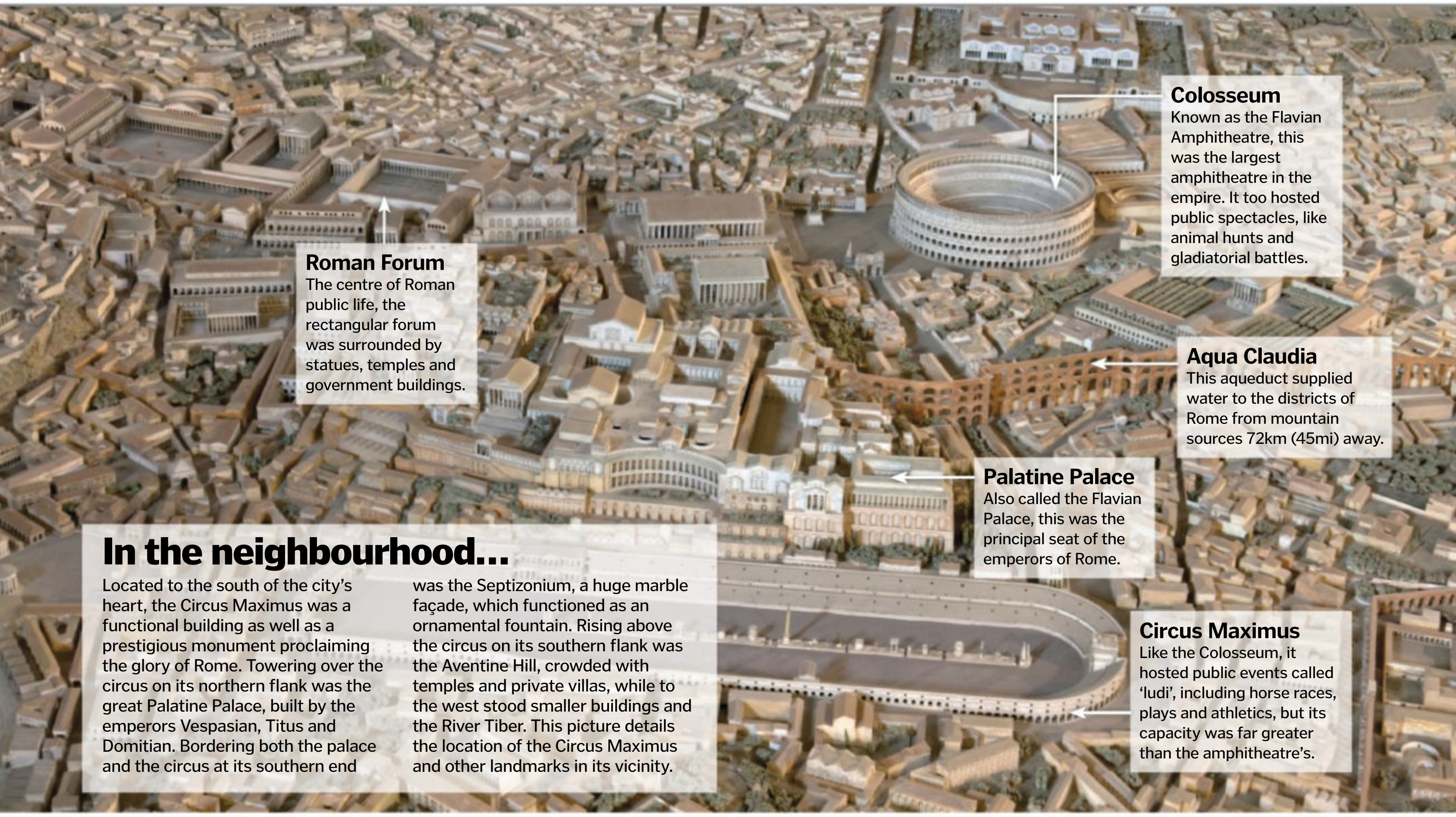
2. BIGGER

Constantinople Hippodrome
450m (1,476ft) in length, the Hippodrome built next to the Great Palace in Constantinople could seat 100,000 spectators.

3. BIGGEST

Circus Maximus
At 621m (2,037) long and with a 250,000 capacity (according to Pliny), this great Roman circus was never surpassed.

DID YOU KNOW? *The celebration for Italy's World Cup 2006 victory was held on the site of the Circus Maximus*



Colosseum
Known as the Flavian Amphitheatre, this was the largest amphitheatre in the empire. It too hosted public spectacles, like animal hunts and gladiatorial battles.

Roman Forum
The centre of Roman public life, the rectangular forum was surrounded by statues, temples and government buildings.

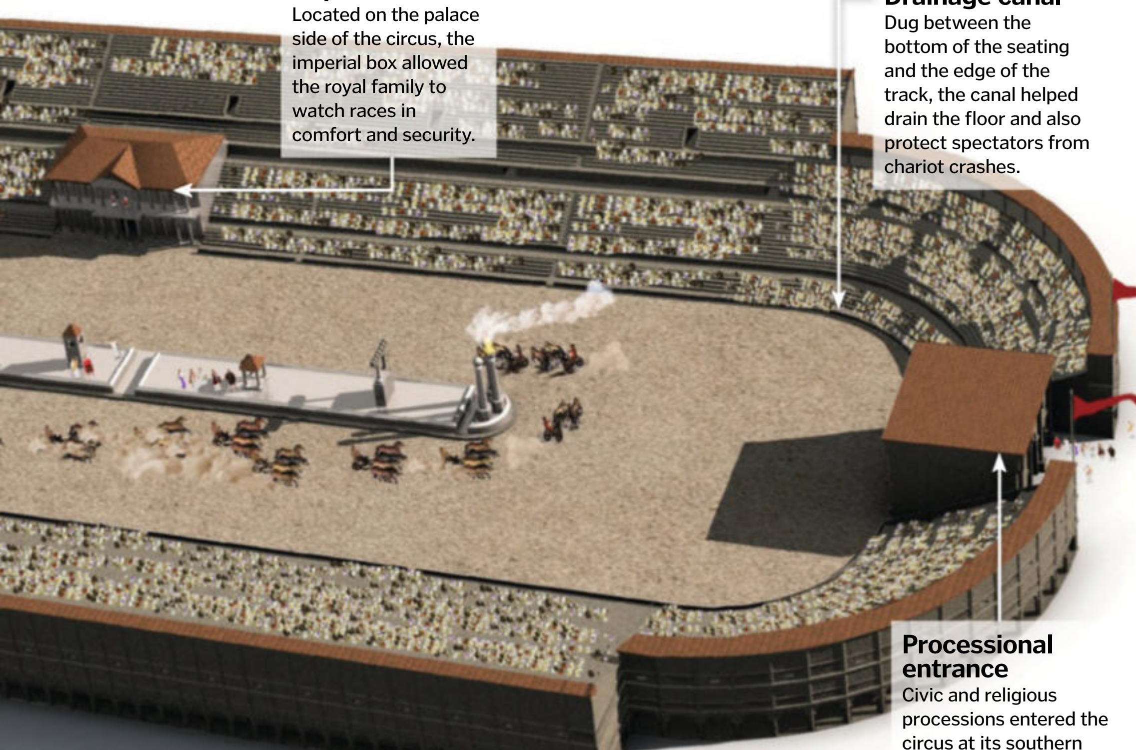
Aqua Claudia
This aqueduct supplied water to the districts of Rome from mountain sources 72km (45mi) away.

Palatine Palace
Also called the Flavian Palace, this was the principal seat of the emperors of Rome.

Circus Maximus
Like the Colosseum, it hosted public events called 'ludi', including horse races, plays and athletics, but its capacity was far greater than the amphitheatre's.

In the neighbourhood...

Located to the south of the city's heart, the Circus Maximus was a functional building as well as a prestigious monument proclaiming the glory of Rome. Towering over the circus on its northern flank was the great Palatine Palace, built by the emperors Vespasian, Titus and Domitian. Bordering both the palace and the circus at its southern end was the Septizonium, a huge marble façade, which functioned as an ornamental fountain. Rising above the circus on its southern flank was the Aventine Hill, crowded with temples and private villas, while to the west stood smaller buildings and the River Tiber. This picture details the location of the Circus Maximus and other landmarks in its vicinity.



Imperial box
Located on the palace side of the circus, the imperial box allowed the royal family to watch races in comfort and security.

Drainage canal
Dug between the bottom of the seating and the edge of the track, the canal helped drain the floor and also protect spectators from chariot crashes.

Processional entrance
Civic and religious processions entered the circus at its southern end under a triple arch erected in honour of Emperor Titus.

Chariot racing in Roman times

Chariot racing was probably the Roman world's equivalent of football. Inherited from the Ancient Greeks and Etruscans, the sport was refined by the Romans and practised throughout the empire. Dangerous to horses and charioteers alike, there were frequent accidents and even deaths during races in the circus.

There could be as many as 24 chariot races in a circus per day and although there were basic rules for behaviour while racing, charioteers often deliberately crashed into opponents or tried to force them into the central barrier.

An average race in the Circus Maximus would see up to 12 teams of charioteers lined up against each other, each chariot drawn by four horses competing over a distance of 6.4 kilometres (four miles). There were four principal teams – the Reds, Whites, Greens and Blues – the latter two of which rose to great prominence.

Fans followed their team's progress closely, much like football clubs do today. Fierce rivalry often resulted in violence between factions and sometimes even riots.

A highly paid sport, the most famous Roman charioteer, Gaius Appuleius Diocles, won 1,462 out of his 4,257 races. When he retired at the age of 42, he had amassed winnings of 35,863,120 sesterces – approximately £9 billion ($15 billion) in today's money – making him the highest-paid sports star in history.

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology and another in real-time computing. He's been writing about science and technology since before the web. His science-fiction novel, *A Jar Of Wasps*, is published by Anarchy Books.

Giles Sparrow

Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in space writing. His latest book, published by Quercus, is *The Universe: In 100 Key Discoveries*.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Vivienne Raper

Vivienne gained a PhD in climate change monitoring before becoming a science journalist. She likes to write science fiction, go on country walks with her dog and play with her glorious collection of over 200 board games.

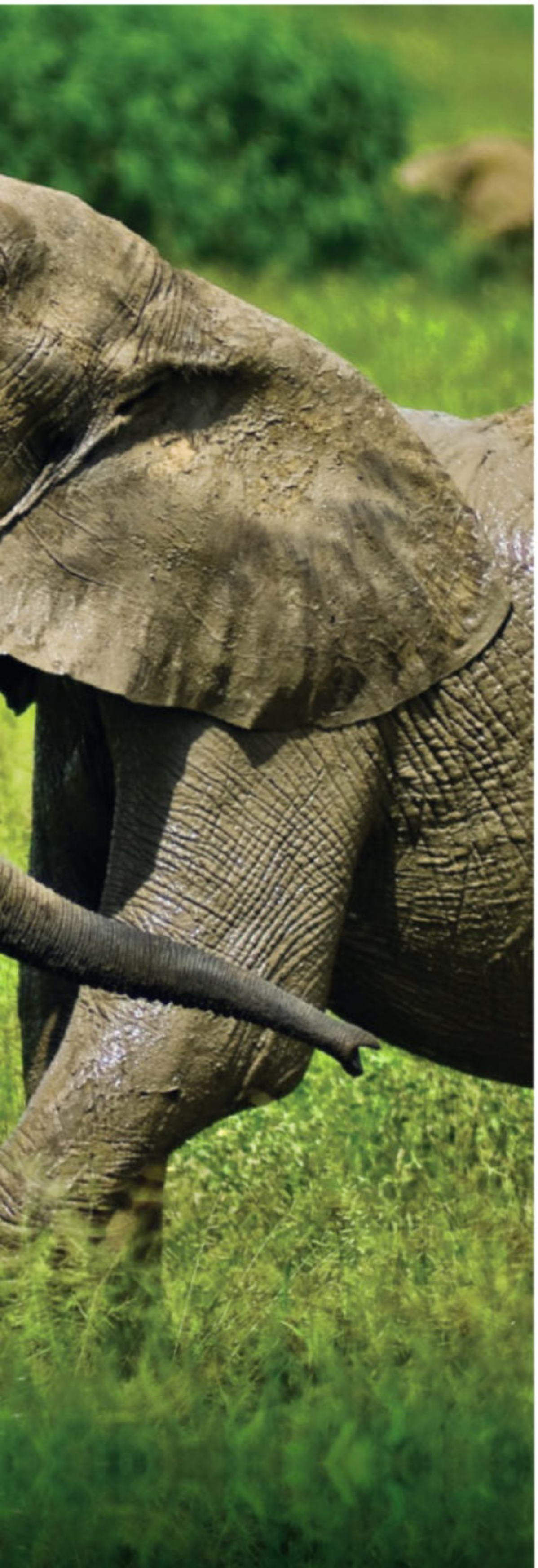
Dave Roos

A freelance writer based in the United States, Dave has written about every conceivable topic, from the history of baseball to the expansion of the universe. He has an insatiable appetite for everything related to science and technology.

How dangerous are elephants?

Marie S

■ To humans, very. An adult African elephant weighs up to 5.5 tons with tusks that can be 2.5 metres (8.2 feet) long and weigh 60 kilograms (132 pounds) each. They can trample you with their feet and knock you out cold with their trunk. Male elephants also undergo a surge in hormones once a year, called musth, which makes them extremely aggressive. In India alone, wild elephants kill about 200 people a year. A study from 1999 found that in just one region of India over a six-year period, 242 people were killed by wild elephants, compared to 90 by wolves, 50 by sloth bears, four by leopards and two by tigers. **LV**

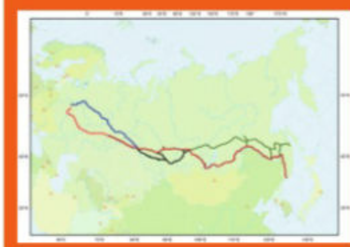


Elephants' immense size and yearly hormone surge can make them extremely dangerous to humans

COOL FACTS

Trans-Siberian trains are time travellers

Stretching between Moscow and Vladivostok, the Trans-Siberian Railway covers 9,258 kilometres (5,753 miles). The journey takes just over a week to complete, crossing seven time zones.



Where are Oscar statues made?

David Washington

Academy Award statues have been made in Chicago, USA in the factory of RS Owens & Company for the past 30 years. Every year, the factory produces around 50 of the 3.9-kilogram (8.5-pound) figurines, designed to resemble a Crusader holding a downward-pointing sword. The original Oscar statues were gold-plated solid bronze, but modern Oscars are cast from a metal alloy called britannium, then coated with 24-carat gold. The process takes ten days from start to finish, although the final touch – a gold plate etched with the winner's name – isn't added until after the awards ceremony itself. **DR**

Why does blond hair look darker when it's wet?

Christopher Madden (8)

Dry blond hair has a rough, tiled surface – something like fish scales. When light rays hit these scales, they bounce off in all directions. Some of the light reaches your eyes and makes the hair look brighter; it's like shining a torch on the hair. When you wash your hair, a thin film of water forms around each fibre. Light rays pass into the film of water, bounce around inside, and there's a chance they'll get absorbed by the hair. Since the light gets trapped inside the water, less of it reaches your eyes, so the hair appears darker. **VR**

Why doesn't the electricity in my body escape to the ground?

Henry Cromie (9)

Our nerves are insulated to prevent the electric signals they produce from escaping. These electrical impulses transmit information to and from the brain, relaying the information gathered by our senses and sending instructions to our muscles. To convey this vital information efficiently, our nerves are coated in a layer of fatty tissue called myelin, which confines the electrical signals to a precise pathway. Myelin prevents electricity from leaking in or out of the nerve, allowing messages to be carried at speeds of up to 400 kilometres (250 miles) per hour. **AC**

Do you age faster in space? Find out on page 82

BRAIN DUMP

Want answers?

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howitworks@ .co.uk

Do we age differently in space?

Graham Jenson

■ Sort of – the lack of gravity on board orbiting spacecraft has some effects that are very like an accelerated form of ageing. For example, muscles begin to waste away with lack of exercise and the strength of your bones deteriorates in a very similar way to the effects of osteoporosis. Your heart also becomes less efficient because it doesn't have to pump blood against gravity. Fortunately, these effects are easily reversed on return to Earth. Ironically, though, travel at high speeds means that, through the strange effects of Einstein's theory of relativity, astronauts actually experience time passing slightly more slowly than those of us on Earth. **GS**

Why is the Namib Desert so foggy?

Leo

■ The Namib Desert lies on the south-western coast of Africa, close to the Benguela Current, which carries cold water northward through the Atlantic Ocean. Fog forms when warm ocean air drifts over this current. The wet air is cooled until the moisture condenses into tiny droplets. The fog is blown inland by prevailing southwesterly winds.

However, other processes can also create fog in this African desert. Desert temperatures drop at night, cooling moist air brought in from the ocean during daytime until fog forms. Air blown uphill as it travels inland can also cool sufficiently to create a fog bank. **VR**

Who invented semaphore?

K Walsgrove

■ The flag semaphore system used by navies around the world evolved from a long line of telegraph systems dating back to ancient times. A 'telegraph' is any kind of long-distance communication system (Greek for 'to write at a distance'). The first telegraphs were smoke signals, fire beacons, reflected light signals, and eventually the semaphore telegraph invented by Claude Chappe in 1792, which used a network of stone towers to transmit messages with a series of pivoting blades or shutters. In the 19th century, naval warships replaced the shutter positions with handheld flags. The US Navy still uses semaphore flags to co-ordinate refuelling at sea. **DR**

How are electronic devices made waterproof?

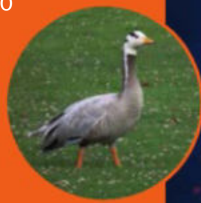
Nigel Vale

■ Electronic devices like smartphones and tablets can be made waterproof by laminating the gadget with a nano-coating a thousand times thinner than a human hair. To apply the coating, the gadget is placed inside a vacuum chamber and exposed to a blast of gas containing a waterproof polymer. The polymer bonds to the surface of the device on a molecular level, coating both external components and the inside surfaces of headphone and Ethernet jacks. The result is a 100 per cent waterproof device that can play *Angry Birds* from the bottom of a fish tank. **DR**

COOL FACTS

Geese are high flyers in the bird world

The bar-headed goose routinely crosses the Himalaya mountain range at altitudes in excess of 7,620 metres (25,000 feet). Its rigorous flapping and thick down keep its body warm as the bird rides tailwinds to airspeeds approaching 160 kilometres (100 miles) per hour.



Wolves once roamed British countryside

King Edward I ordered the total extermination of wolves back in the 13th century but allegedly the last wolf wasn't killed until 1743, by a famous hunter called MacQueen.

Saffron is worth its weight in gold

Extracted from the flowers of a particular type of crocus, saffron is widely acknowledged as the world's rarest and most expensive spice. It can take 16,000 flowers to make just 100 grams (3.5 ounces) of it!

What new tech was used at the Winter Olympics?

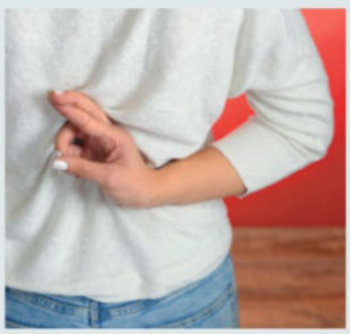
E Robichaud

Some of the greatest technological leaps at the 2014 Winter Olympics in Sochi, Russia, were hidden in the athletes' suits and sleds. The US speed-skating team sported the world's fastest bodysuit, a collaboration between sports-clothing company Under Armour and aerospace engineering firm Lockheed Martin. 3D models of athletes in various skating positions were placed in Lockheed's wind tunnels to test hundreds of fabrics. The winning design had tiny rubber bumps and fins that reduced turbulence as the skater glides through the air. The US bobsled, luge and skeleton teams replaced old sleds with carbon-fibre models engineered by BMW Designworks out of bespoke composite materials developed by chemical company Dow. Wind tunnel testing delivered a lighter, smoother ride with tighter driver control. Even the curling brooms were given an upgrade, replacing brush heads with a smooth insulated fabric that raises the ice temperature nearly 30 per cent with a few short sweeps. **DR**

How does glow-in-the-dark paint work?

Raif Sadik

Glow-in-the-dark paint contains a chemical called phosphor that absorbs energy and then releases it as visible light. When exposed to light, the phosphor atoms' electrons are bumped up to a higher energy state. They remain in this state temporarily, storing the energy from the light. As the electrons drop back down to lower-energy states over time, they release the energy, emitting a faint glow. There are many different types of phosphor, but most glow-in-the-dark objects use strontium aluminate, which gives off a characteristic green light for several hours. **AC**



Why do we cross our fingers for luck?

Ranjit Bedi

Most historians think the crossed-fingers gesture is a reference to the Christian religion and the sign of the cross in particular. Early Christians were widely persecuted in the Roman Empire, and one theory is that the sign began as a secret way of showing your faith and recognising fellow believers. Its modern association with good luck probably originated with Christians 'calling on the sign of the cross' for protection. Crossing your fingers when you tell a lie, meanwhile, may have started out as a way of calling on the cross to protect you from being punished for fibbing! **GS**

What can Schrödinger's cat teach us?

Geoff Winters

Schrödinger's cat is a thought experiment stating that objects at the quantum scale can exist in multiple states at once. In this hypothetical situation, a cat is placed in a box along with a radioactive sample and a phial of poisonous gas. Two outcomes are possible. If a radioactive atom decays, it releases the poison, killing the cat. If no atom decays, the cat remains alive. The odds of either outcome are equal. According to quantum physics, until somebody observes the atoms, they are in a state of superposition, meaning they are simultaneously decayed and undecayed. So until someone opens the box, the cat is both dead and alive. This paradox shows how bizarre the implications of quantum physics are. **AC**

Is it possible to predict earthquakes? Find out on page 84

I've heard dolphins rescue people but do other animals?

Rhys Plummer

In 2004, eight-year-old Amber Mason was saved from the tsunami in Thailand when a young elephant carried her to safety. But this is less impressive when you realise that Amber was already riding the elephant on the beach when the wave struck. Similarly, cats have accidentally saved their owners lives by meowing loudly when the house is on fire, but they were probably actually meowing to be let out themselves. Nevertheless, genuine animal rescues do sometimes happen. In 2007, Scottish farmer Fiona Boyd was violently attacked by one of her cows who thought her calf was threatened. Her horse Kerry rode to the rescue and kicked at the cow to drive it off. And in 2005, lions saved a 12-year-old girl in Ethiopia by scaring away her kidnappers and then standing guard over her. It's not clear whether they would have eaten her if the police hadn't turned up though. **LV**

Many animals, even lions, have shown evidence of altruism

COOL FACTS

Snail shells were once used to help keep our teeth clean

Before modern toothpaste came along, people used many different ingredients to clean teeth and freshen breath. These included charcoal, bark, powdered ox hooves, pumice, crushed bone and ginseng, as well as oyster and snail shells.

How do earthquake early-warning systems work?

Val Pullman

Scientists can't predict when an earthquake will strike, but they can detect when one has already begun. They measure vibrations called P waves, which arrive at detectors tens of seconds before the strongest shaking. From the P waves, they can estimate the energy of the quake. The warning time varies depending on the distance between the detectors and the epicentre of the quake.

Mexico City, among the few cities with a public warning system, receives more than a minute of warning. That's enough for people to hide beneath a table, to brake trains to stop them from derailing, or isolate hazardous factory chemicals. **VR**

If you get diamonds on other planets, are there other gemstones too?

Jack (10)

Diamonds are probably common on other planets because they're made of pure carbon, and carbon itself is a common element throughout the universe. Chemistry works in the same way on other planets, but other gemstones have more complex structures involving a variety of elements (some of which are much rarer than carbon), so Earth-like gems and minerals might only occur on Earth-like planets. Many gemstones also form only in the presence of water, so they would require a wet, Earth-like environment to develop. **GS**

The 'seas' on the Moon have nothing to do with water but ancient lava flows

Why are there 'seas' on the Moon – did it once have water?

Emily Rudge

■ The term 'seas' (or in Latin, maria) was invented by German astronomer Johannes Kepler in 1610, shortly after the invention of the telescope. Kepler, like many before him, thought that the dark patches on the surface of the Moon were bodies of water similar to Earth's oceans, but within a few years, improvements to telescopes showed that this was not the case – the 'seas' are actually smooth dark plains pockmarked by occasional craters. Today we know the 'seas' are actually solidified remains of huge lakes of lava that erupted onto the Moon's surface more than 3 billion years ago and filled in low-lying impact basins created by earlier collisions. So the lunar seas were never filled with water – but there's still good evidence for water ice, brought to the Moon by comets, buried in the ground close to our satellite's cold north and south poles. **GS**

Where did totem poles originate?

Lynne Knowles

■ Totem poles aren't religious idols to be worshipped; they are marker posts to proclaim family and clan affiliations for a household – much like a flag. They only date back to around 1700, when metal tools first became available to the tribes of Alaska and British Columbia in Canada. Some totem poles celebrate the achievements of a particular person, and there are also 'shame poles' that were erected to humiliate the chief of a nearby village into repaying a debt. The idea the figures carved higher up the pole are more important is a myth. The vertical ordering is usually insignificant. **LV**

How do we bring a person out of a coma?

Brad Meller

■ When we talk about 'bringing someone out of a coma', we are referencing medically induced comas. A patient with a traumatic brain injury is deliberately put into a deep state of unconsciousness by doctors in order to reduce swelling and allow the brain to rest. When the brain is injured, it becomes inflamed, something like a swollen knee. The swelling damages the brain because it is squished inside the skull. Doctors induce the coma using a controlled dose of drugs. To bring the person out of the coma, they simply stop the treatment.

Bringing the patient out of the coma doesn't wake them immediately. They gradually regain consciousness over days, weeks or longer. Some people make a full recovery, others need rehabilitation or lifetime care and others may remain unaware of their surroundings. How well they emerge from the coma depends on the severity of the injury and where it occurred in the brain. **VR**

How is silk manufactured?

Naomi

■ Silkworm caterpillars secrete silk as a liquid protein called fibroin. This stiffens into a solid filament on contact with air. The caterpillar glues this into a cocoon, using a different sticky protein, called sericin. But before the caterpillars get a chance to change into moths, silk farmers boil the cocoons in water to kill the caterpillars and dissolve the sericin coat. The boiled cocoons are combed until the loose end unravels and then the thread is fed onto spools and spun. It takes five to ten silk fibre strands to make a single thread and 6,000 caterpillars to manufacture a single kilogram (2.2 pounds) of silk. **LV**

Trivia on your tablet

■ The latest edition of **How It Works**' digital sister magazine **Brain Dump** is due to hit the virtual newsstand on 1 April. In issue 11 you'll learn how deodorant helps tackle sweat, take a look at the tech inside the Global Hawk drone aircraft, and find out whether we'll ever be able to build mega-bots like those in *Pacific Rim*. And that's just for starters! **Brain Dump** is the perfect companion for anyone who likes to learn new trivia, but doesn't want the hassle of constantly carrying a magazine or books. Download the new issue from iTunes or Google Play on the first day of every month. You can ask your own questions at **www.facebook.com/BraindumpMag** or Twitter – @BrainDumpMag.

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Before taking out your new cycling gear for a spin, check out our tips for sprucing up your bike after its post-winter slumber on page 92

Ultimate cycling kit

Unleash your inner Bradley Wiggins with this selection of cutting-edge cycling gear

As winter turns to spring, bikes are being brought out of hibernation and intrepid fitness enthusiasts are making those first tentative steps to prove that we really never forget how to ride a bike. While a pair of shorts and a helmet might be all you need for a pedal around the block, those looking to head a little farther afield would be wise to invest in some more high-tech equipment to make sure you and your two-wheeled steed are operating at peak performance. Check out our roundup now!

Checklist

- ✔ Helmet
- ✔ Jersey
- ✔ Tights
- ✔ Mask
- ✔ Light
- ✔ Lock
- ✔ GPS
- ✔ Tyre

The DACC is a 95 per cent charcoal weave that filters out the primary pollutants found in vehicle exhausts. It was originally developed by the UK Ministry of Defence for use against chemical warfare.

The seat inserts use a microfibre fabric for good moisture management and a pelvic tract to support road-bike body position.

1 Head protection
Giro Monza Road Helmet
£79.99/$N/A
www.tredz.co.uk
Helmets can sometimes be heavy and cumbersome, but the lightweight Giro Monza Road Helmet feels like it's not even there. Featuring 24 sculpted wind vents it keeps your head cool, is quite easy to adjust and, if all that wasn't enough, it looks seriously cool too.
Verdict: ●●●○○

2 Extra pockets
Gore Oxygen Jersey
£89.99/$129.99
www.goreapparel.com
Lightweight and flexible, this jersey hugs you warmly without being restrictive and uses innovative tech to wick away the unavoidable sweat. The best thing about it though is the rear pockets, which don't sag or ever feel imbalanced and are easily accessible.
Verdict: ●●●●●

3 Padded power
Gore Power 3.0 tights
£89.99/$119.99
www.goreapparel.com
Very comfortable to ride in, these three-quarter-length tights are nice and warm and the padded seat insert makes for a very comfortable journey. Most interesting is the fact that the padding is optimised depending on the length of your journey.
Verdict: ●●●●○

4 Fighting pollution
Respro City
£26.99/$N/A
www.tredz.co.uk
A dynamic activated charcoal cloth keeps the worst of urban pollution like car fumes out, but it is quite uncomfortable, pinching the nose and, after an oxygen-burning climb, it leaves you out of breath. But on flat city roads this would really come into its own.
Verdict: ●●●○○

5 Safety light
Lezyne Power Drive XL
£84.99/$99.99
halfords.com / lezyne.com
Lightweight, sleek and stylish, this powerful light will safely guide you home at night. It lasts for up to over 11 hours and charges via USB or plug in just four to six hours. Grooves in the sides make you more visible to cars emerging from sideroads.
Verdict: ●●●●○

6 Tough lock
New York Fahgettaboudit
£77.99/$109.95
halfords.com / krytonitelock.com
This 2.9-kilogram (6.4-pound) lock may add a lot of weight to your bike and not reach too far to allow for flexible locking, but it is made of super-tough kryptonium steel, uses a double deadbolt mechanism and has a Gold Sold Secure safety rating.
Verdict: ●●●●○

7 Route master
Garmin Edge 510 GPS
£299.99/$329.99
www.maplin.co.uk / www.garmin.com
This cycle computer is excellent for the casual cyclist who just wants to know their speed and time, as well as the enthusiast who wants to plan training routes and know their power output. It can sync with mobile devices too.
Verdict: ●●●●●

8 Puncture free
Bell Mountain Bike Tyre
£11.48/$19.96
direct.asda.com / www.walmart.com
One of the most frustrating things for any cyclist is a puncture, but that should be a thing of the past with this tyre. It is Kevlar coated to provide exceptional puncture resistance and also sports a carbon-steel bead for durable wear on the road.
Verdict: ●●●●○

Coolmax pads absorb sweat, pulling it away from your head and to the outside of the pads, allowing the moisture to evaporate.

Forged with kryptonium steel, this lock is capable of resisting virtually any cutting tool and small enough to make leverage attacks difficult too.

This technology is geared towards longer battery life with a rechargeable lithium-ion battery, Intelligent Power Indicator button and flashing energy-saving mode.

This mini Garmin computer can get a signal from GPS and GLONASS satellites to ensure rapid and accurate speed and distance readings.

Kevlar is a very strong synthetic material, which requires a huge amount of force for its fibres to get separated, meaning glass and thorns will struggle to pierce it.

The rear pockets are built in to the jersey and supported with a harness-like structure to make sure they don't sag during the journey.

EXTRAS

Get in to cycling without having to push a pedal…

BOOK

Bradley Wiggins: My Time

Price: £8.99/$18.95
Get it from: randomhouse.co.uk
Read the account of Bradley Wiggins' career, culminating in his double victory at the Tour de France and the London 2012 Olympics. Just as Wiggins himself, it's honest, entertaining and absorbing.

APP

Strava

Price: Free
Get it from: iTunes/Google Play
One of the most popular cycling apps on the market, Strava provides you with all the cycling data you need, giving you precise data about your rides. It also has a direct link to social media sites to share your stats.

WEBSITE

www.bikeradar.com

If you want to talk about anything bike related, this is the place to go online. Bike Radar is a huge cycling website that discusses everything from the relative merits of carbon vs aluminium forks to how to get your kids into the habit of cycling every day, as well as how to best teach them the ropes.

GROUP TEST

Putting products t

Four objective lenses
The area in which this microscope excels is its objective lenses. They are clearly marked, easily handled and the 60x lens gives a startlingly detailed view of the slide.

Digital microscopes

Get a really close look at the gadgets that help you get a really close look at your science projects

LCD screen
The LCD screen gives you a comfortable viewing experience, with the image on screen responding instantly to your manipulation of the focus knob. The buttons and menu are easily navigable and both the photos and video captured with it look amazing.

From any angle
The best thing about this microscope has to be the fact that you can pick up the viewer and move it around. This allows you to view things closely in ways you're unable to with fixed microscopes, creating the opportunity for new angles and more dynamic videos.

1 LCD Digital Microscope II

Price: £245/$199.95
Get it from: www.celestron.uk.com
The first thing we noticed about this Celestron microscope was how quickly we were able to go from opening the box to taking snaps of the slides. The LCD Digital Microscope II has three objective lenses of 4x, 10x and 40x power magnification, which is plenty for your average home scientist. But the coolest thing about this product has to be the 8.9-centimetre (3.5-inch) LCD screen, which provides a squinty-eyehole-free viewing experience. The buttons on the screen make for a user-friendly experience, as a menu button, two navigation buttons and an action button are all you need. Switching between shooting videos and pictures is also simple and the playback is immensely satisfying. Celestron provides a 1GB SD card – allowing you to take 625 hi-res images or 20 minutes of video - five prepared slides with an array of interesting features, and plug adaptors for a range of countries. If you want to get creative, there are also a number of filters to play with, both digitally and on a physical filter wheel. The entire experience of using this microscope is very enjoyable and the added extras mean you can get to work straight away.
Verdict:

2 PentaView LCD Digital Microscope

Price: £419/$419.95
Get it from: www.celestron.uk.com
The PentaView is another breed of microscope, also with an LCD display for much easier viewing. This model comes with all the required power cables as well as ten slides, including bamboo and some fascinating leaf veins. It also has one microscope more than the LCD Digital Microscope II, allowing viewers to get even closer to the action with a 60x objective lens. The downside to this model is that the LCD display doesn't seem to be the clearest. We found the image looks quite grainy, like a slightly untuned TV. Also, for some unknown reason, the display suddenly turned purple during the test. The video and photo function work well and, although the touchscreen technology makes it seem the most high-tech, it's not always very responsive and the layout on the display menu isn't as clear as it could be. All the controls are extremely responsive though and the array of slides is impressive and allows for a lot of really interesting viewing from the get-go, however that LCD display does let the side down a bit.
Verdict:

3 Handheld Digital Microscope Pro

Price: £140/$119.95
Get it from: www.celestron.uk.com
This is pretty much the entry-model microscope, perfect for getting a closer look at things that are small, but not that small. Attempting to view the slides from the other two packs is only slightly different than if we just put our face really close to it. The image is nice and sharp and the five-megapixel camera allows us to take some nice pictures of whatever we put on the viewing platform. The main benefit of this product is its manoeuvrability. You are able to detach the microscope from its cradle and move it around, inspecting your subject from any angle, which can be useful. Rather than using an LCD display, you instead have to install Celestron software onto your computer and plug in the microscope via the USB port. It's nice being able to view the image on the large computer screen, it's easy to take photos and the video quality is decent enough, but switching between the computer and the microscope is a bit of a chore. As a starter model this microscope gets a good, clear photo, but it isn't likely to thrill a more seasoned enthusiast.
Verdict:

ON THE HORIZON

What else would we like to get our hands on in the near future?

Motorised skateboards

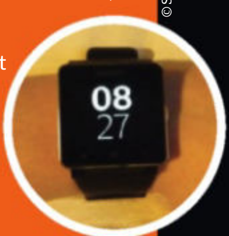
It's not quite the hoverboard from *Back To The Future*, but it's not far off. The ZBoard could spark a commuting revolution by responding to forward and backward motions and applying power accordingly. The 400-watt electric motor can reach 27km/h (17mph), which could make frustrating drives, sweaty cycles or tedious walks a thing of the past.

iPhone charging cases

One of the main bugbears with smartphones is their battery's inability to last much more than a day. Luckily, SunPartner Technologies is working on a crystal screen for the iPhone 5 and 5s, which recharges the battery using the power of the Sun – probably one more for the US market than the UK!

Smartwatches

With smartphones linked up to Facebook, Twitter and email, we seemingly have to get our phones out every five minutes. However, the latest wave of smartwatches will hopefully end all that palaver, letting you see in a second whether that bleep was a comment on your Facebook photo or another spam email.



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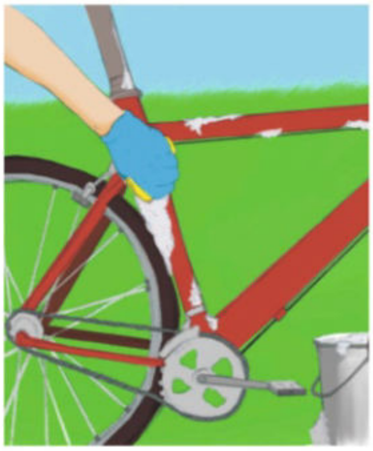
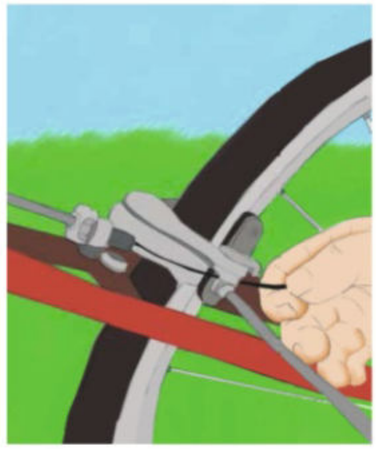
Service your bike

As winter departs, here are some top tips to rouse your bike from hibernation



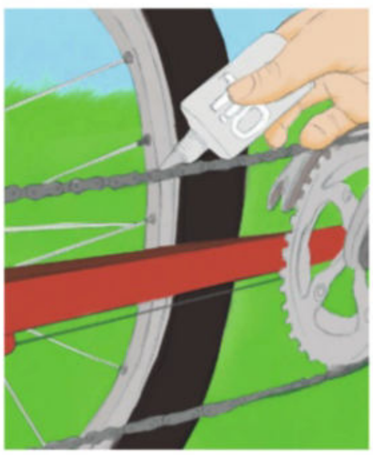
1 Wash up

The first thing you will need to do when prepping your bike for the spring is to give it a good clean. All manner of mud, dirt and foliage may have gotten into the many moving parts, so using warm, soapy water and a cloth, give your bike a good wipe over. Pay attention to the rear brake callipers, as a lot of mud gathers there, which could hamper your brakes' efficiency. Don't forget to clean the frame's underside too.



2 Brake test

Next it's a good idea to take a good, close look at your brake pads. If the rubber part is less than 0.6cm (0.25in) thick then they need to be replaced. If, when you squeeze the brake, the pads don't, or barely, reach the wheel, take out the screw clamping the brake wire to the mechanism. Pull the wire through a little more and screw it back in. The brakes should now be closer to the wheel rim and therefore more effective.

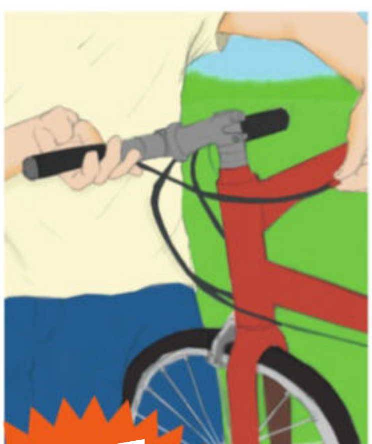


3 Oil everything

If your bike has been sitting around for a while or been used in the rain it could have become a bit rusty. Use some 3-in-1 oil or chain oil and apply generously to the brake mechanism, the chain, the cassette and the brake cables. When applying it to the chain, turn the bike upside down and rotate the crank, applying oil as the chain moves round for even coverage. You'll be able to see when it has gone a full circle.

4 Check your wheels

Release the wheels from the frame and remove the tyres and inner tube from the wheel. Carefully run a finger along the inner rim to check for anomalies that could cause punctures, such as a spoke sticking through. Look inside the tyre for glass shards or thorns. Pump the inner tube up and submerge it in water to see if there are any slow punctures. If you see any bubbles rising, patch up any holes, before putting wheels back on the bike.

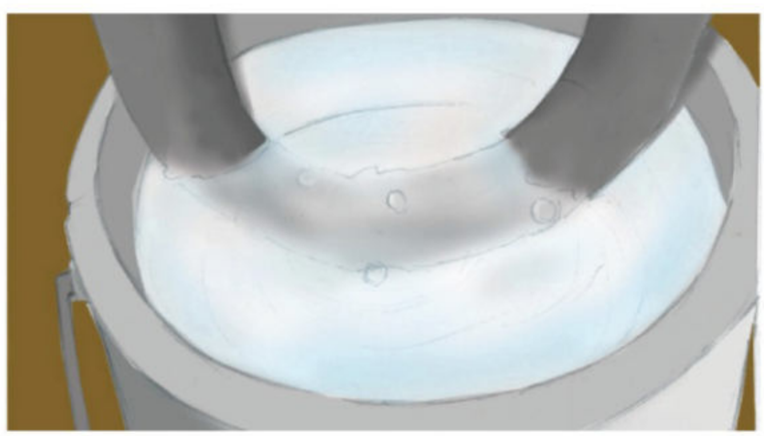


5 Replace brake cables

If your brakes are sticking or the brake cable is frayed, it may need replacing. When buying new cables, make sure the end of the new cable matches up with the old. Using an Allen key, undo the pinch bolt and the barrel-like adjuster that attaches the cable to the brake lever. Pull it out of the casing and cut the new cable to the same length. Thread the new cable back into the casing, reattach into the brake lever and bolt it back into the wheel housing.

In summary…

After carefully scrutinising the bike all over and replacing rusty and thin nuts and bolts, you're good to go. Servicing your bike yourself can save a lot of money, because most bike shops only check the bike over and oil moving parts – which you can easily do yourself. Expert advice and replacements will usually only be required if something is obviously damaged, such as a buckled wheel, dented fork or wobbly crankshaft.



NEXT ISSUE
- Hunt for buried treasure
- Save on fuel

Make cool Easter eggs

With Easter fast approaching, dress up your eggs for unique displays and egg hunts

1 Boil the eggs
Place all the eggs you want to decorate in a saucepan and completely cover with water. Bring the water to the boil, then reduce the heat and allow it to simmer for about ten minutes. When the eggs are hard-boiled, remove them and place them in cold water for a couple of minutes before putting them into the fridge to keep cool. They should be ready for you to decorate within an hour. Use this time to prepare your colourful egg-painting materials.

2 Mix the dye
Drop a dye pellet, which can be bought at most craft shops, into a cup of water or vinegar. You can also use half a cup of water, a tablespoon of vinegar and about 20 drops of food colouring. Allow to settle and infuse. Alternatively you can make natural colourings by boiling items like red cabbage (blue eggs) and spinach (green), but the colours will generally be less intense. Prepare at least three cups of different colours at once for easier and quicker dyeing.

3 Get decorating
If you want to add extra decorations, put patterned strips of tape on your egg. Carefully place the egg in the dye solution, leaving for at least three minutes. Remove the egg and allow it to dry. Make it even more attractive by dipping half in one solution and half in another, using a paintbrush to layer softer levels of dye on the egg or re-applying tape to the dyed areas and re-dipping for a tie-dye effect. Always let the eggs dry before dipping in a new solution.

In summary...
Apart from boiling the eggs and adding vinegar to the dye solution, it really is up to your imagination when it comes to making your own Easter eggs! Experiment with all sorts of different colour blends and patterns. Store them in the fridge till needed.

AIRFIX

QUICK QUIZ

Test your well-fed mind with ten questions based on this month's content and win a model of the Cutty Sark clipper!

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. What was the name of the famous cloned sheep?
2. How many square kilometres are lost by desertification in China every year?
3. Who was the first person to use knots in surgery?
4. Which part of a cell is responsible for producing energy for the cell?
5. What is the cushion of air around a moving football called?
6. What is the Ant Nebula's astronomical name?
7. Which ancient civilisation constructed the Circus Maximus stadium?
8. During which decade were lawnmowers invented?
9. What was the first name of Foucault, whose pendulum proved that Earth rotates?
10. How many time zones does the Trans-Siberian Railway cross?

ISSUE 57 ANSWERS
1. 18% **2.** 1967 **3.** Yellow **4.** -18°C **5.** 42 **6.** 40cm
7. 1824 **8.** Latex **9.** 19 **10.** Pungi

INBOX
Speak your mind...

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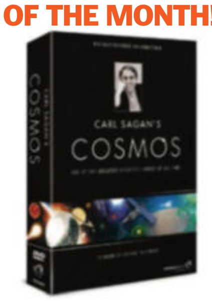
WIN!
We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!



GO ON A JOURNEY THROUGH SPACE!

Next issue's Letter of the Month will win Carl Sagan's *Cosmos: A Personal Voyage* – a digitally remastered 13-hour series re-released to tie in with new Nat Geo show *Cosmos: A Spacetime Odyssey*.

Letter of the Month

Wake up with the blues!

Dear **HIW**,
The fact about blue light from the '10 Cool Things' section in issue 55 got me thinking.

Apparently this phenomenon is partly due to the fact that we have cells in our eyes that control our body clock. They only respond to blue light though.

I was wondering why that is. I think it could either be that the blue light from the Sun is refracted all over the sky, so you don't have to be looking at the Sun for the cells to work, or that the Sun's light peaks in the blue-green part of the spectrum. What do you think?

Thanks for the info. I've now bought a colour-changing light bulb so I can switch it to blue to help me wake up in the morning. It works really well!
Laura Bradby (13)

Hi Laura,
Yes, blue light has been demonstrated to improve our cognitive function as well as to boost our energy levels.

While the Sun does undoubtedly have an effect, it is more likely to be the fact that blue light increases psychomotor function and reduces melatonin levels in the brain. Melatonin is a hormone that regulates sleep so reducing its levels keeps you more alert.

However, be careful with too much artificial light before bedtime as it can knock your body clock out of sync. It is best to turn off artificial light, such as computer screens and mobile phones, just before bed to allow the body to unwind.

Hope you enjoy some bedtime reading with our illustrated history of physics winging its way to you!

Blue light has been shown to help wake us up in the mornings

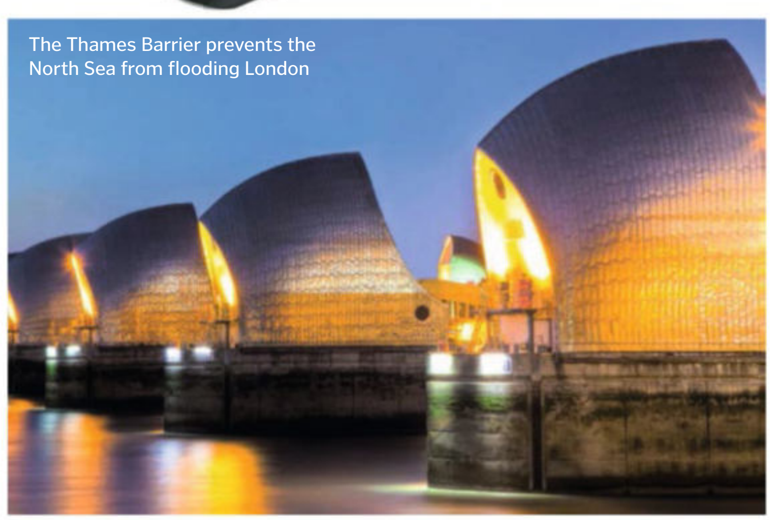
Water world

Dear **HIW**,
Just like to say great work on the mag. I especially enjoyed the feature on megafloods in issue 57. It really puts the weather we're having at the moment in perspective! It is amazing to think that we were once part of [mainland] Europe and at one point the English Channel didn't even exist. I also never knew the Thames Barrier was so hi-tech. Its importance to the city of London doesn't get enough recognition in my opinion. I think you can soon add Britain to your list of flood-prone places though!
Hannah Collins

Hi Hannah,
Good to hear you enjoyed the article. As we all know, Britain has had its fair share of wet weather recently, with the Met Office declaring it the wettest winter on record, but megafloods were on a whole other scale. And we agree, it is strange to think that we could once take a stroll over to France!

Boats to blame?

Dear **How It Works**,
This letter is to ask why no one is questioning that sea rising is down to water displacement? Ships displace large amounts of water. You fill the bathtub up for one person and then, if a second person gets in, you end up with water all over the floor. I can't see why it would be any different for the sea when you think of all the ships out there from warships to



The Thames Barrier prevents the North Sea from flooding London

"Britain has had its fair share of wet weather… but megafloods were on a whole other scale"

oil tankers and cruise ships all displacing a massive amount of water. I can clearly see why sea levels are rising. I think this is the big driver to climate change and carbon dioxide emissions are only boosting the weather effects, not creating them.

This does not give energy companies the green light to keep using fossil fuels though. Critics of climate change cannot deny this fact one bit. We need to stop adding ships to the sea – maybe even reduce large ships that displace over 'x' amount of water.

What we class as extreme weather events now could just become normal so what will the new extreme weather events be like in the future? Countries completely flooded? I think we'll find out soon enough.

Sincerely,
Rob

This is an interesting theory, Rob. Sea levels are reportedly rising at about three millimetres (0.12 inches) a year and yes, there are more ships and boats in the oceans than before. But the oceans and seas are so vast that rising sea levels caused by the amount of vessels in the water is tricky to prove. The effect of warmer water expanding more than cold water and the melting of the polar ice caps are much likelier culprits.

An astronomical correction

To How It Works,
In school I am doing the project 'space' and I have noticed there is a mistake on page 34 (issue 56). It says, 'These in order from the Sun, are Saturn, Jupiter, Uranus and Neptune'. The correct way is Jupiter, Saturn, Uranus and Neptune.
Alexandra Moll (9)

Thanks for pointing this out, Alexandra. Of course you're right about the order of the planets and we can only apologise for missing this error. It's more a case of red face than Red Spot! Good luck with the project – we're sure you'll get top marks.

What's happening on… Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month…

Ashwin Kumaar @ashwinkumaar10
@HowItWorksmag I've always wondered why metal 'sparks' in the microwave

krs @KRS_OVO
Just bought the digital version of **@HowItWorksmag** I'm addicted!

Princess Lea Savoy @Lea Savoy
@HowItWorksmag
@HowItWorks Best magazine ever! How can I subscribe in the US? I get my copies from @costco for now

Ollie Iron @Ollie_Iron
@HowItWorksmag Gathering up leaves & twigs into carrier bags, searching them for bugs, putting them under microscope. Wouldn't happen today

Tom R @blockswitch
Just got the latest **@HowItWorksmag** + it's about 3d printers :)

Andy Shelley @Andy2k64
@HowItWorksmag glad you've done a mag on 3D printing. This is the most exciting and promising tech at the moment! :)

Gary McNicol @IslayGaz
@HowItWorksmag
You guys really need to produce a binder. 57 issues just laying around my house! #NotVeryTidy

PHS Technology Dept. @phstd
The latest **@HowItWorksmag** has a great article about 3D printing. Should probably get a subscription for the dept!

HOW IT WORKS

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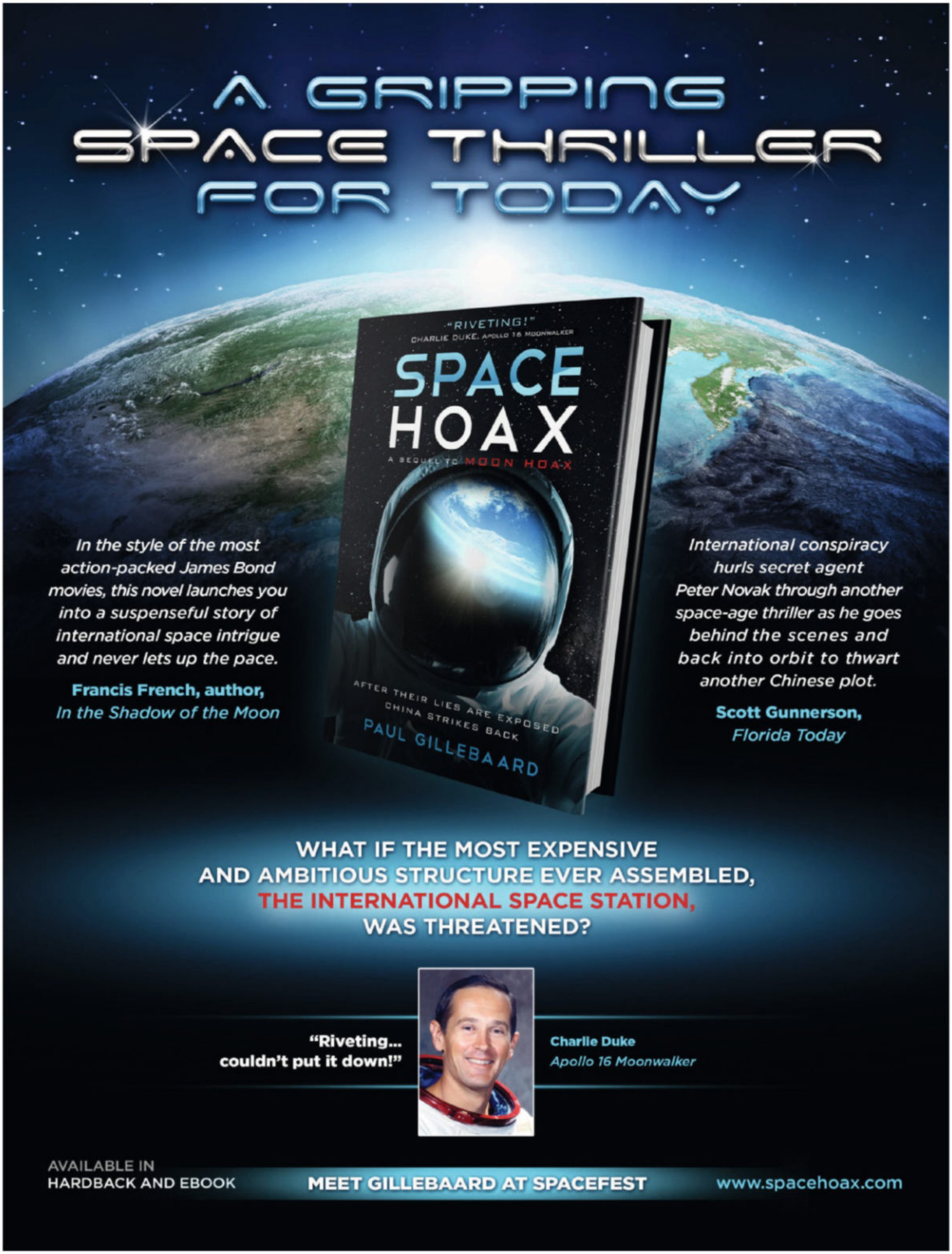
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How are buildings designed to turn a full 360 degrees?

Why is chickenpox such a contagious ailment?

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